GJO–2003–400–TAC

Hanford Tank Farms Vadose Zone Monitoring Project

Annual Monitoring Report for Fiscal Year 2002

January 2003

U.S. Department of Energy

GRAND JUNCTION OFFICE

Work Performed Under DOE Contract No. DE–AC13–02GJ79491 for the U.S. Department of Energy
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Prepared for
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Grand Junction, Colorado

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1.0 Introduction

The Hanford Tank Farms Vadose Zone Monitoring Project (VZMP) was established in fiscal year (FY) 2001 for comprehensive routine monitoring of existing boreholes in Hanford single-shell tank farms. The logging system used for monitoring is the Radionuclide Assessment System (RAS). A baseline record of existing contamination associated with gamma-emitting radionuclides in the vadose zone was established between 1995 and 2000 using the Spectral Gamma Logging System (SGLS). Although less precise, the RAS is a simpler, faster, and more cost-effective logging system than the SGLS. Measurements collected with the RAS can be compared to the baseline data to assess the long-term stability of the radionuclide contaminant profile. When routine monitoring identifies anomalies relative to the baseline, these anomalies may be investigated using the SGLS, the High Rate Logging System (HRLS), and/or the Neutron Moisture Logging System (NMLS). The HRLS is also used to collect data in boreholes where the contaminant activity exceeds the working range of the RAS instrumentation (greater than about 100,000 picocuries per gram [pCi/g] cesium-137 [^{137}Cs]).

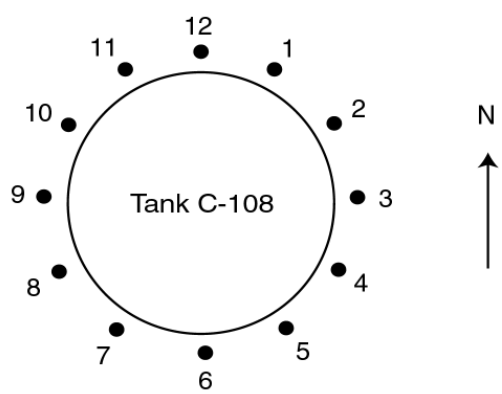
Routine quarterly reports are issued to summarize the results of monitoring activities, to provide the status of any on-going special investigations, and to provide an updated listing of borehole intervals where monitoring is planned in the coming months. This annual report summarizes monitoring activities for FY 2002 and includes fourth quarter and project-to-date results where appropriate.

For readers not familiar with the Hanford Tank Farms borehole numbering scheme, the following illustration shows how to identify the location of a borehole from its identification number:

Tank Farm Numbering Scheme

A Farm	10
AX Farm	11
B Farm	20
BX Farm	21
BY Farm	22
C Farm	30
S Farm	40
SX Farm	41
T Farm	50
TX Farm	51
TY Farm	52
U Farm	60

Tank Farm Borehole Numbering Scheme



Boreholes are identified by numbers using the format FF-TT-PP, where "FF" = tank farm, "TT" = tank, and "PP" = the position around the tank in a time-clock numeral from 1 to 12 (12 = north). For example, borehole 30-08-02 is in the C Tank Farm, around tank C-108, and at approximately the 2 o'clock position.

2.0 Monitoring Results

Summaries of monitoring operations for the fourth quarter of FY 2002 and project-to-date are included in Tables 2-1 and 2-2, respectively.

Table 2-1. Summary of Monitoring Operations for 4th Quarter of FY 2002

Month	July	August	September	Total
Borehole Events	15	48	81	144
Main Log Footage	890.5	2749.5	4583.5	8223.5
Rerun Log Footage	50	100	190	340
Total Footage	940.5	2849.5	4773.5	8563.5

Table 2-2. Summary of Monitoring Operations for FY 2002 and Project-to-Date

Quarter	1	2	3	4	FY 2002 Total	Project-to-Date Total
Borehole Events	54	74	113	144	385	498
Main Log Footage	3351	4287	5483.5	8223.5	21345	27358
Rerun Log Footage	195	195	274	340	1004	1418
Total Footage	3546	4482	5757.5	8563.5	22349	28776

Appendix A is a table that provides further details of boreholes monitored during FY 2002, including borehole number, tank number, logging depths and footage, total score, next projected monitoring date, dates of HRLS logging events, dates of RAS monitoring events, and a comment section. This table is derived from the project's monitoring database, which is continually updated as boreholes are monitored (DOE 2001). Boreholes are selected by a priority score (total score) that emphasizes proximity to tanks with significant drainable liquid remaining and/or the presence of contaminant plumes or where possible contaminant movement is suspected. The most significant change that occurs in the database is the monitoring frequency. Where monitoring results suggest possible contaminant movement, the monitoring frequency and monitoring depth intervals may be changed.

During the fourth quarter of FY 2002, evidence of contaminant movement was identified in three boreholes: 30-08-02 in C Farm, 50-06-18 in T Farm, and 60-05-05 in U Farm. The attached plots (Appendix B) show a comparison of the RAS and the SGLS baseline measurements for these boreholes and indicate the depth intervals of suspected contaminant movement. The dominant contaminants detected in these boreholes are cobalt-60 (^{60}Co) and processed uranium (uranium-238 [^{238}U]) and uranium-235 [^{235}U]).

Data collected in September 2002 from borehole 30-08-02 (C Farm) exhibited evidence of recent migration of ^{60}Co at depths of approximately 47 to 61 feet (ft) and 67 to 75 ft. The area of contamination originates between tanks C-108 and C-109 and extends downward and to the east. The ^{60}Co migration detected in borehole 30-06-10 in 1999 (Bertsch 1999) and confirmed by RAS measurements in April 2002 may be related to the same area of contamination. A memorandum transmitted by e-mail from Rick McCain (S.M. Stoller) to Robert Yasek (DOE-ORP) dated September 17, 2002 (Appendix C) provides a more detailed discussion of these anomalies. Quarterly monitoring for these boreholes has been established with the next measurements scheduled for December 2002.

Data collected in T Farm from borehole 50-06-18 showed a possible increase in ^{60}Co between 117 and 119 ft in depth in a September 2002 measurement. This possible concentration increase was not observed in two prior RAS measurements collected in August 2001 and January 2002. The monitoring frequency for this borehole has been changed to quarterly and the next measurement is scheduled for December 2002.

Routine monitoring (not related to tank U-107 retrieval operations) of borehole 60-05-05 in U Farm indicated possible processed uranium contamination migration between 75 and 80 ft in depth. This borehole did not show any change in July 2001 when RAS data were compared to the SGLS baseline data because the RAS depth interval was not deep enough for comparison. As a result, monitoring intervals have been extended to the total depth in selected U Farm boreholes. The monitoring frequency for borehole 60-05-05 has been changed to quarterly.

In addition to the three boreholes discussed above, Table 2-3 lists all the boreholes that have indicated potential changes in radionuclide contaminant profile since the inception of the monitoring project in June 2001. Plots for the respective boreholes are included in the referenced quarterly or fiscal year reports.

Table 2-3. Summary of Monitored Boreholes Indicating Radionuclide Contaminant Profile Changes

Tank Farm	Borehole Number	Radio-nuclide	Deter-mined	Number of Events	Assessment	Assigned Frequency	Qtrly/Annual Report
BX	21-27-08	$^{238}U/^{235}U$	03/13/02	3	Not confirmed	6 mos.	2nd 2002
BY	22-03-04	^{60}Co	11/15/01	2	Not confirmed	6 mos.	1st 2002
BY	22-07-02	^{60}Co	11/29/01	2	Not confirmed	6 mos.	1st 2002
BY	22-07-05	^{60}Co	12/12/01	2	Not confirmed	6 mos.	1st 2002
BY	22-08-05	^{60}Co	03/30/99	2	Not confirmed	6 mos.	1st 2002
C	30-06-10	^{60}Co	03/03/97	1	Possible increase	3 mos.	3rd 2002
C	**30-08-02**	**^{60}Co**	**09/11/02**	**2**	**Definite increase**	**3 mos.**	**FY 2002**
SX	41-02-02	$^{137}Cs/^{90}Sr$	09/07/01	3	Not confirmed	6 mos.	FY 2001
T	50-01-09	^{60}Co	07/30/01	4	Not confirmed	6 mos.	FY 2001
T	50-06-02	$^{60}Co/^{154}Eu$	07/18/01	4	Not confirmed	6 mos.	FY 2001
T	50-06-03	^{60}Co	07/18/01	4	Not confirmed	6 mos.	FY 2001
T	50-06-18	^{60}Co	09/03/02	3	Possible increase	3 mos.	FY 2002
T	50-04-10	^{60}Co	01/28/02	3	Possible confirmation	3 mos.	2nd 2002
T	50-09-01	$^{60}Co/^{154}Eu$	07/23/01	4	Not confirmed	6 mos.	FY 2001
T	50-09-02	^{60}Co	01/08/02	2	Not confirmed	6 mos.	2nd 2002
T	50-09-10	$^{60}Co/^{154}Eu$	07/23/01	4	Not confirmed	6 mos.	FY 2001
TX	51-03-11	^{60}Co	05/20/02	1	Possible increase	3 mos.	3rd 2002
TY	**52-03-06**	**^{137}Cs**	**05/02/02**	**3**	**Definite change**	**3 mos.**	**3rd 2002**
TY	52-06-05	^{60}Co	05/14/02	1	Possible increase	3 mos.	3rd 2002
U	60-04-08	$^{238}U/^{235}U$	07/16/01	5	Not confirmed	3 mos.	FY 2001
U	60-05-05	$^{238}U/^{235}U$	08/27/02	2	Possible increase	3 mos.	FY 2002
U	60-07-01	$^{238}U/^{235}U$	07/12/01	5	Not confirmed	3 mos.	FY 2001

In the interest of brevity, plots for boreholes where no apparent change was observed are not included in quarterly or fiscal year reports. These logs are available on request.

3.0 Special Investigations

A special investigation of boreholes in the vicinity of tank U-107 (U Farm) continues. This investigation was initiated in June 2001 at the request of Robert Yasek (DOE-ORP) to support waste retrieval operations. A preliminary evaluation of log data in the vicinity of tank U-107 (Bertsch 2001) is included in Appendix D. A comparison of SGLS and RAS data indicates downward movement of processed uranium between 1995 and 2001 in boreholes 60-07-01, 60-07-10, and 60-07-11; movement in the latter two boreholes was determined by comparison of two SGLS measurements prior to 2001. The fifth quarterly monitoring event for selected boreholes was completed on August 27, 2002. No significant changes in contaminant profile have been observed in the four monitoring events since the initial event conducted in June 2001. It is likely that the elapsed time between monitoring events is not sufficient to detect subtle changes in contaminant profile resulting from slow movement of contaminants in the vadose zone. However, routine monitoring in a borehole in the vicinity (60-05-05) appears to have detected movement of processed uranium. This borehole will also be monitored on a quarterly basis until waste retrieval operations are completed. Because of the possible downward and lateral movement of contaminants, the logging depth intervals will be extended to total depth in each borehole. These boreholes are scheduled on a quarterly basis and the next scheduled monitoring event in U Farm is November 2002. The changes in contaminant profile discussed above are evidence of continued movement of a pre-existing contaminant plume and are not related to tank U-107 retrieval operations, which had not started at the end of FY 2002.

During the third quarter, a verbal request was received from CH2M Hill Hanford Group (CHG) personnel to monitor boreholes around tank S-112 in S Tank Farm, in advance of planned retrieval operations during FY 2003. RAS data were collected in six boreholes during June 2002 to provide a baseline to which future measurements collected during waste retrieval operations can be compared. When compared to baseline SGLS data, the RAS data showed no apparent changes. The six boreholes have been tentatively placed on a monitoring frequency of 6 months (biannual) until retrieval monitoring requirements are defined.

During May 2002, routine RAS monitoring in borehole 52-03-06 (TY Farm) detected a prominent ^{137}Cs peak between 55 and 57 ft that was not present during the baseline SGLS logging in 1996. This peak was subsequently confirmed by additional SGLS measurements. A "new" area of contamination appears to be present at or slightly below the base of the tank farm excavation (Occurrence Report PER2002-2444). Appendix E (Bertsch 2002) includes a more detailed discussion of this anomaly.

During August 2002 moisture logging was performed in boreholes in the vicinity of the anomalous ^{137}Cs activity. A 13-ft interval of high moisture (12 to 35 percent) was detected between 38 and 51 ft in depth in borehole 52-06-02. This borehole is located approximately 75 ft west of borehole 52-03-06 and may be in the vicinity of a water source that has mobilized contaminants to the location of borehole 52-03-06. Appendix F includes a plan view map of TY Farm and a cross section plot that depicts the spatial relationships of contaminants, moisture, and lithology (based on ^{40}K concentrations).

Since the monitoring project started in June 2001, one or more regions of high gamma flux that are beyond the range of the RAS detection system have been identified in 25 tank farm boreholes. HRLS data are required from these boreholes to assess potential changes. During the third and fourth quarters of FY 2002, 14 and 10 boreholes, respectively, had been logged; one borehole (41-09-04) could not be logged because of contamination inside the borehole casing, as determined from a borehole swab. Table 3-1 provides a summary of the HRLS logging during the fiscal year that includes the borehole, date of logging, the footage collected with each shielding configuration, date of the last RAS logging event, and an assessment of the data results when comparisons with HRLS logging conducted in 1999 were made.

Table 3-1. Summary of High Rate Logging

Borehole	Date of Logging	NS[1] (ft)	ES[2] (ft)	IS[3] (ft)	Both[4] (ft)	Repeat (ft)	Date of RAS Log	Comment
20-10-12[5]	***07/03/02***	***55.0***	***0***	***28.0***	***0***	***0***	***09/09/02***	***No apparent change***
21-02-04	06/27/02	151.0	0	65.0	0	0	09/04/01	No apparent change
21-07-06	05/20/02	0	12.0	0	0	0	09/05/01	No apparent change
21-10-03	05/21/02	18.0	0	17.0	0	0	08/30/01	No apparent change
22-03-05	***07/16/02***	***0***	***0***	***18.0***	***0***	***0***	***12/20/01***	***No apparent change***
40-02-03	04/25/02	0	10.0	0	0	0	None	No apparent change
40-04-05	04/24/02	10.0	0	5.0	0	0	06/11/02	No apparent change
41-07-05	04/19/02	0	0	0	6.0	0	09/25/01	No apparent change
41-07-07	04/19/02	0	0	0	11.0	0	04/09/02	No apparent change
41-08-07	04/18/02	0	0	0	9.5	0	09/25/01	No apparent change
41-08-11	04/19/02	0	0	0	13.0	0	09/26/01	No apparent change
41-09-03	04/22/02	0	0	11.0	0	0	09/26/01	No apparent change
41-09-07	04/22/02	0	0	9.0	0	0	04/05/02	No apparent change
41-11-10	04/18/02	8.0	00	0	0	0	04/09/02	No apparent change
41-12-02	04/23/02	25.0	16.0	4.0	0	0	10/03/01	No apparent change
50-01-04	***07/24/02***	***92.5***	***0***	***14.0***	***0***	***0***	***08/07/01***	***No apparent change***
50-06-04	***07/29/02***	***0***	***6.5***	***0***	***0***	***0***	***07/23/01***	***No apparent change***
50-06-05	***07-26-02***	***69.5***	***0***	***17.0***	***0***	***0***	***08/06/01***	***No apparent change***
50-06-06	***07/29/02***	***11.0***	***0***	***0***	***0***	***0***	***07/24/01***	***No apparent change***
50-06-08	***07/29/02***	***0***	***0***	***5.5***	***0***	***0***	***07/25/01***	***No apparent change***
50-06-17	***07/30/02***	***37.5***	***16.0***	***3.0***	***0***	***0***	***08/07/01***	***No apparent change***
60-10-07	***07/18/02***	***0***	***0***	***4.5***	***0***	***0***	***08/26/02***	***No apparent change***
60-12-01	***07/17/02***	***33.0***	***0***	***18.0***	***0***	***0***	***11/06/01***	***No apparent change***
52-03-03	05/13/02	0	0	5.5	0	5.5	05/14/02	No apparent change
Total Footage		510.5	60.5	224.5	39.5	5.5	840.5	

[1]NS – no shield; [2]ES – external shield; [3]IS – internal shield; [4]Both – both internal and external shields;
[5] bold and italics are boreholes logged in the 4th quarter of FY 2002

4.0 Operational Issues

During the fourth quarter of FY 2001, an average of approximately 1.5 boreholes were monitored per working day. This rate incorporates all operational aspects of monitoring, including both scheduled and unscheduled down time for maintenance, operator support, security, etc. The rate of monitoring achieved during each successive quarter during FY 2002 improved from 1.0 borehole per day during the first quarter to 2.2 boreholes per day during the fourth quarter. The project goal is to achieve an average of 3 boreholes per day.

The increase in monitoring rate throughout the year was due to a decrease in down time and improved efficiency during monitoring operations. The improved efficiency was most apparent during the fourth quarter of FY 2002. Although the total down time during this quarter had increased from the previous quarter, operators were willing to help make up the lost schedule. Nine overtime shifts were also worked to make up the schedule during the fourth quarter of

FY 2002. The lack of dedicated RAS operators, Health Physics Technicians' (HPTs) support, and equipment problems continue to factor in recorded down time. CHG and Stoller are both aware that these issues continue to affect the productivity of the monitoring project and are attempting to improve the performance.

Tables 4-1 and 4-2 include summaries of production and operational issues, respectively, that affect monitoring production.

Table 4-1. Summary of Monitoring Production (Project-to-Date)

Quarter	Total Work Days	Total Days Down	Total Monitoring Events	Boreholes Monitored per Day
4th of FY01	56	29.3	84	1.5
1st of FY02	56	35.2	54	1.0
2nd of FY02	55	34.1	74	1.3
3rd of FY02	59	21.1	113	1.9
4th of FY02	66	27.6	144	2.2
FY02 Total	236	118.0	385	1.6
Cumulative Total	292	147.3	469	1.6
Average/Quarter	58.4	29.5	93.8	1.6

Table 4-2. Summary of Operational Down Time

Quarter	Equipment/ Truck Problems (hrs)	No HPT/ Operator Support (hrs)	Security Measures (hrs)	No Charge Code or Administrative (hrs)	Moving Truck (hrs)	Weather (hrs)	Misc. (hrs)	Total Down Time (hrs)
4th of FY01	64	130	20	27	20	3	0	264
1st of FY02	107	84	51	44	14	13	4	317
2nd of FY02	143	40	24	58	9	18	15	307
3rd of FY02	30.5	62	0	36	27	8	26	189.5
4th of FY02	81	122	0	0	37	0	8	248
FY02 Total	361.5	308	75	138	87	39	53	1061.5
Cumulative Total	425.5	438	95	165	107	42	53	1325.5
Average/Quarter	85.1	87.6	19.0	33.0	21.4	8.4	10.6	265.1

5.0 Lessons Learned

A lessons learned paper regarding the RAS (Appendix G) was submitted to Robert Yasek (DOE-ORP) in December 2001 to document deficiencies with the RAS and to provide recommendations for development and implementation of borehole logging systems for the monitoring project. The most significant findings and recommendations were to provide for (1) an updated and ergonomically correct logging vehicle and (2) the ability to detect contamination concentrations of 10^9 pCi/g ^{137}Cs equivalent. A recommendation was made to procure a conventional logging system that would be supplemented by development of a high rate detector compatible with the new logging system. It was also strongly recommended that the conventional logging sonde include neutron moisture capability in addition to spectral gamma. This capability would allow gamma and moisture data to be concurrently collected. Excess moisture due to water leaks and/or infiltration is recognized as the primary factor in contaminant migration.

At the end of FY 2002 a larger vehicle with more headroom and legroom for the operators was procured. The operator's station in this new vehicle has been reconfigured to resolve ergonomic issues. Transfer of the RAS equipment to this vehicle will be completed in early FY 2003.

6.0 Summary

The RAS has proved useful in providing a credible monitoring program for the tank farms vadose zone. Three hundred eighty-five monitoring events were performed with the RAS in FY 2002. A total of 498 monitoring events have been performed since the beginning of the project in June 2001. An additional 24 boreholes were monitored during FY 2002 with the HRLS, and moisture measurements were collected in seven boreholes. The high priority boreholes in all tank farms have been monitored at least once.

Evidence of possible contaminant movement has been detected in 25 boreholes in seven tank farms. Of these 25 boreholes, data collected from two boreholes indicate movement to a degree that can be confirmed over a short time interval. Of the remaining 23 boreholes it is likely that the elapsed time between monitoring events is not sufficient to detect subtle changes in contaminant profile, suggesting relatively slow movement of contaminants in the vadose zone. In general, intervals where discernable movement of contaminants through the vadose zone is occurring within short periods of time (e.g., < 1.5 years) appear to be very limited. This finding, corroborated with continued measurements, will be useful to select appropriate remedial actions for tank farm closure and/or removal of contaminated soil.

7.0 Future Monitoring Operations

Appendix H provides a summary by tank farm of prioritized boreholes available for monitoring through the end of the first quarter of FY 2003. This list includes all boreholes with a total score greater than 20 and a next monitoring date that is overdue or will become overdue within 90 days. High rate logging or moisture measurements are not considered in this list but will be conducted concurrently with the RAS monitoring as resources are available.

Boreholes are selected by a priority score that emphasizes proximity to tanks with significant drainable liquid remaining and/or the presence of contaminant plumes or where possible contaminant movement is suspected. Approximately 180 boreholes score relatively high and require monitoring at frequencies of 1 year or less. The remaining tank farm boreholes scheduled to be monitored (approximately 550) have relatively low-priority scores and are scheduled for a 5-year monitoring frequency. On the basis of FY 2002 monitoring production, approximately seventy-five 5-yr boreholes can be logged annually. This monitoring schedule enables the project to achieve a project goal of monitoring all the tank farm boreholes at least once in 5 years while maintaining closer scrutiny on the most important boreholes. Because many of the low-priority boreholes score essentially the same, it is prudent to re-prioritize some of these boreholes so that monitoring can begin at an earlier date. This re-prioritization has occurred for boreholes in the vicinity of tanks that are currently undergoing salt well pumping even though little fluid is being introduced into these tanks. Because C Tank Farm is being considered for early closure, many of the boreholes in this farm will be monitored at an earlier date relative to the initial prioritized score.

8.0 Issues

A credible monitoring program is essential to demonstrate the long-term stability of subsurface contaminant plumes and to identify areas in which contaminant migration is occurring. Furthermore, monitoring of existing drywells before, during, and after retrieval operations is an important component of the overall leak detection process. The current monitoring program is based on the deployment of a single RAS. It may be necessary to provide additional monitoring systems as the scope of the waste retrieval program increases. Future logging systems should be based on commercially available mineral/geotechnical/environmental logging equipment. These systems will be capable of both gamma/spectral gamma and neutron moisture measurements using a conventional sonde. Additional detectors will be necessary to provide reliable measurements in zones where contaminant activities are as high as 10^9 pCi/g ^{137}Cs.

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Appendix A
Boreholes Monitored During FY 2002

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
11-01-09	AX-101	45	85	40		66	09/21/03		09/26/02					No apparent change
11-01-10	AX-101	45	73	28		66	08/31/07		09/26/02					No apparent change
11-01-11	AX-101	45	85	40		66	08/31/07		09/26/02					No apparent change
20-05-06	B-105	35	120	86		34	09/20/03		09/25/02					No apparent change
20-12-03	B-109	35	99	64		31	09/20/03		09/25/02					No apparent change
20-11-09	B-111	35	75	40	10	35	09/20/03		09/25/02					No apparent change
20-06-06	B-106	35	100	69		33	09/19/03		09/24/02					No apparent change
20-03-06	B-103	35	75	40		35	09/18/03		09/23/02					No apparent change
20-02-09	B-105	35	99	64	10	34	09/18/03		09/23/02					No apparent change
20-08-02	B-108	35	105	70		30	09/18/03		09/23/02					No apparent change
20-09-06	B-109	35	101	66		31	09/18/03		09/23/02					No apparent change
20-12-06	B-111	35	75	40		35	09/18/03		09/23/02					No apparent change
20-08-07	B-108	35	80	45	10	30	09/14/03		09/19/02					No apparent change
20-10-12	B-110	102	120	18		37	09/14/03	07/03/02	09/19/02					No apparent change
40-01-01	S-101	40	80	40		29	08/24/07		09/19/02					No apparent change
40-01-06	S-101	30	80	50	10	29	08/24/07		09/19/02					No apparent change
40-02-04	S-102	40	80	40	10	14	08/24/07		09/19/02					No apparent change
40-02-11	S-102	40	80	40		14	08/24/07		09/19/02					No apparent change
40-10-09	S-110	40	80	40		5	08/24/07		09/19/02					No apparent change; special request
40-01-04	S-101	40	80	40		29	08/22/07		09/17/02					No apparent change
40-01-08	S-101	40	80	40		29	08/22/07		09/17/02					No apparent change
40-01-10	S-101	35	80	45		29	08/22/07		09/17/02					No apparent change
40-02-01	S-102	40	80	40		14	08/22/07		09/17/02					No apparent change
40-02-05	S-102	40	80	40		14	08/22/07		09/17/02					No apparent change
40-02-07	S-102	20	80	60		39	09/12/03		09/17/02					No apparent change
40-02-08	S-102	20	85	65		39	09/12/03		09/17/02					No apparent change
40-02-10	S-102	40	80	40	10	14	08/22/07		09/17/02					No apparent change
40-03-05	S-103	40	90	50		39	09/12/03		09/17/02					No apparent change
40-08-06	S-108	40	80	40	10	0	08/22/07		09/17/02					No apparent change
40-09-08	S-109	40	80	40		2	09/12/03		09/17/02					No apparent change; special request
40-03-03	S-103	40	80	40		14	08/21/07		09/16/02					No apparent change
41-08-02	SX-108	40	75	40		40	09/11/03		09/24/01	09/16/02				No apparent change
51-14-04	TX-114	40	97	62		34	09/11/03		09/16/02					No apparent change
30-08-02	C-108	30	99	69	79	27	12/11/02		09/11/02	09/12/02				Definite change in Co-60 49-75 ft
51-01-06	TX-101	40	80	40		28	09/07/03		09/12/02					No apparent change
51-01-08	TX-101	40	90	50		28	09/07/03		09/12/02					No apparent change
51-00-07	TX-104	40	110	70		29	09/07/03		09/12/02					No apparent change
51-14-08	TX-114	40	85	45	10	34	09/07/03		09/12/02					No apparent change
51-14-11	TX-114	40	99	59		34	09/07/03		09/12/02					No apparent change
51-16-04	TX-116	35	80	45		38	09/07/03		09/12/02					No apparent change
30-03-05	C-103	30	80	50		29	08/16/07		09/11/02					No apparent change
30-03-07	C-103	30	70	40		29	08/16/07		09/11/02					No apparent change
30-05-10	C-105	10	70	60		31	09/06/03		09/11/02					No apparent change
30-06-04	C-106	20	100	80	10	38	09/06/03		09/11/02					No apparent change
30-09-01	C-109	30	99	69		30	09/06/03		09/11/02					No apparent change

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
30-09-02	C-109	30	100	70		30	09/06/03		09/11/02					No apparent change
30-09-07	C-109	30	100	70	10	30	12/10/02		09/11/02					No apparent change
30-09-10	C-109	25	98	73		30	09/06/03		09/11/02					No apparent change
30-09-11	C-109	30	99	69		30	09/06/03		09/11/02					No apparent change
30-12-01	C-112	30	70	40		27	09/05/03		09/10/02					No apparent change
30-12-13	C-112	25	70	45	10	27	09/05/03		09/10/02					No apparent change
41-01-06	SX-101	25	80	55	10	39	09/04/03		09/06/01	09/09/02				No apparent change
41-02-08	SX-102	40	80	40		70	09/04/03		09/10/01	09/09/02				No apparent change; possible Sr-90
41-02-11	SX-102	20	80	60	10	70	09/04/03		09/07/01	09/09/02				No apparent change
41-08-04	SX-108	35	76	41		52	09/04/03		09/17/01	09/09/02				No apparent change
41-11-09	SX-111	40	75	35	10	41	09/04/03		09/17/01	09/09/02				No apparent change
21-10-05	BX-110	46.5	98	57		41	09/03/03		09/06/01	09/08/02				No apparent change; requires HRLS
41-01-10	SX-101	40	80	40		51	09/01/03		09/07/01	09/06/02				No apparent change
41-02-02	SX-102	25	140	115		82	03/05/03		09/07/01	03/26/02	09/06/02			Possible change not confirmed; possible Sr-90
41-00-08	SX-109	40	89	49		58	03/05/03		08/20/01	03/28/02	09/06/02			No apparent change
41-12-07	SX-112	40	73	33		26	08/11/07		09/06/02					No apparent change
41-12-09	SX-112	40	75	35		26	08/11/07		09/06/02					No apparent change
21-04-08	BX-107	35	100	65		36	08/31/03		08/29/01	09/05/02				No apparent change
21-07-03	BX-107	35	100	65		36	08/31/03		08/29/01	09/05/02				No apparent change
21-08-12	BX-109	35	80	45	10	33	08/31/03		08/29/01	09/05/02				No apparent change
21-10-01	BX-110	35	75	40		41	08/31/03		08/30/01	09/05/02				No apparent change
21-00-02	BX-102	35	97	62		81	08/30/03		08/13/01	09/04/02				No apparent change
21-02-03	BX-102	35	99	64	10	106	03/03/03		08/14/01	03/13/02	09/04/02			No apparent change
21-02-06	BX-102	35	99	64		94	08/30/03		08/15/01	09/04/02				No apparent change
21-27-01	BX-102	35	99	64		106	03/03/03		08/28/01	03/13/02	09/04/02			No apparent change
21-27-02	BX-102	35	96	61		94	08/30/03		08/20/01	09/04/02				No apparent change
21-27-07	BX-102	35	139	104	10	94	08/30/03		08/15/01	09/04/02				No apparent change
21-27-08	BX-102	35	149	114		106	03/03/03		08/14/01	03/13/02	09/04/02			Apparent change 137.5-148.5 ft not confirmed
21-27-09	BX-102	35	149	114		94	08/30/03		08/16/01	09/04/02				No apparent change
21-27-10	BX-102	30	149	119		94	08/30/03		08/13/01	09/04/02				No apparent change
21-27-11	BX-102	30	137	107	10	106	03/03/03		08/20/01	03/14/02	09/04/02			No apparent change
21-03-03	BX-103	35	90	55		54	03/03/03		08/28/01	02/25/02	09/04/02			No apparent change
21-12-02	BX-109	35	75	40		33	08/30/03		08/29/01	09/04/02				No apparent change
50-06-16	T-106	30	86	61		130	08/29/03		07/24/01	09/03/02				No apparent change
50-06-18	T-106	25	130	110		143	12/02/02		08/01/01	01/29/02	09/03/02			Possible increase 117-119 ft (Co-60)
50-04-10	T-104	35	88	53	10	55	11/27/02		07/31/01	01/22/02	08/29/02			Apparent change 67-68 ft
50-00-10	T-106	30	70	40		93	08/24/03		07/18/01	08/29/02				No apparent change
50-06-02	T-106	30	122	92	10	143	02/25/03		07/19/01	11/07/01	01/15/02	08/29/02		Apparent change at 110 ft not confirmed
50-01-06	T-101	30	87	57		50	08/23/03		07/30/01	08/28/02				No apparent change
50-01-09	T-101	30	90	60	10	62	02/24/03		07/30/01	11/08/01	01/22/02	08/28/02		Apparent change at 86-90 ft not confirmed
50-01-12	T-101	30	70	40		37	08/23/03		07/30/01	08/28/02				No apparent change
50-02-05	T-102	30	85	55		55	02/24/03		07/25/01	01/22/02	08/28/02			No apparent change
50-04-08	T-104	30	96	66		55	02/24/03		07/31/01	01/24/02	08/28/02			No apparent change
50-05-11	T-105	30	120	90		39	08/23/03		07/25/01	08/28/02				No apparent change
50-00-09	T-106	30	120	90		143	02/24/03		07/18/01	01/09/02	08/28/02			No apparent change

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
50-06-03	T-106	30	118	88		143	02/24/03		07/18/01	11/12/01	01/15/02	08/28/02		Apparent change at 115 ft not confirmed
50-09-10	T-109	30	120	90		54	02/24/03		07/23/01	11/07/01	01/16/02	08/28/02		Apparent change at 76 and 94 ft not confirmed
50-06-11	T-106	30	83	53		118	08/22/03		07/19/01	08/27/02				No apparent change
50-09-01	T-109	30	86	56	10	54	02/23/03		07/23/01	11/08/01	01/28/02	08/27/02		Apparent change at 85 ft result of water level
50-09-02	T-109	30	86	56		54	02/23/03		01/08/02	08/27/02				Apparent change 81-86 ft caused by different water lev
60-04-08	U-104	40	110	70		94	11/25/02		07/16/01	10/22/01	01/03/02	04/10/02	08/27/02	Apparent change (74-78 and 84-89 ft) not confirmed
60-04-10	U-104	35	94	59	10	69	08/22/03		07/16/01	08/27/02				No apparent change
60-05-04	U-105	35	72	37		44	11/25/02		07/16/01	10/24/01	08/27/02			No apparent change
60-05-05	U-105	35	80	45		44	11/25/02		07/16/01	08/27/02				Possible increase 75-80 ft
60-08-04	U-108	35	100	65		56	11/25/02		07/09/01	10/25/01	12/28/01	04/15/02	08/27/02	No apparent change
60-11-03	U-111	35	75	40		12	08/01/07		08/27/02					No apparent change
60-07-10	U-107	40	99	59	10	85	11/24/02		07/09/01	10/24/01	12/27/01	04/15/02	08/26/02	Apparent change (SGLS); 53-65 ft not confirmed
60-07-11	U-107	40	100	60		85	11/24/02		07/12/01	10/24/01	12/27/01	04/15/02	08/26/02	Apparent change (SGLS); 73-95 ft not confirmed
60-10-01	U-110	35	75	40		11	11/24/02		07/17/01	10/04/01	12/27/01	04/11/02	08/26/02	No apparent change
60-10-07	U-110	35	75	40	10	36	08/21/03	07/18/02	07/17/01	08/26/02				No apparent change
60-10-11	U-110	35	75	40		11	11/24/02		07/17/01	10/04/01	01/02/02	04/11/02	08/26/02	No apparent change
60-11-05	U-111	35	53	18		12	07/31/07		08/26/02					No apparent change; obstruction at 53 ft
60-11-06	U-111	35	75	40		12	07/31/07		08/26/02					No apparent change
60-07-01	U-107	40	98	58		85	11/21/02		07/12/01	10/04/01	12/26/01	04/10/02	08/23/02	Apparent change 83-88 ft not confirmed
60-07-02	U-107	35	100	65		53	11/21/02		07/12/01	10/04/01	12/26/01	04/15/02	08/23/02	Apparent decrease 90-100 ft not confirmed
60-00-06	U-111	35	75	40		12	07/28/07		08/23/02					No apparent change
60-00-08	U-112	35	73	38		12	07/28/07		08/23/02					No apparent change
52-01-05	TY-101	35	80	45	10	26	08/17/03		08/22/02					No apparent change
52-01-09	TY-101	35	99	64		26	08/17/03		08/22/02					No apparent change
52-02-11	TY-102	35	80	45		29	08/17/03		08/22/02					No apparent change
52-03-06	TY-103	40	100	60		55	11/20/02		05/02/02	05/21/02	08/22/02			Definite change 55-60 ft; report issued 5/14/02
22-09-08	BY-109	20	97	80	10	30	08/16/03		08/21/02					No apparent change
22-02-09	BY-102	20	80	60		31	08/15/03		08/20/02					No apparent change
22-07-07	BY-107	40	99	59		68	02/16/03		12/12/01	08/20/02				No apparent change
22-04-07	BY-104	40	100	60		31	08/14/03		08/19/02					No apparent change
22-08-12	BY-108	30	90	60		74	02/15/03		12/13/01	08/19/02				No apparent change
22-09-11	BY-109	20	80	60		30	08/08/03		08/13/02					No apparent change
22-10-10	BY-110	40	98	58	10	28	08/08/03		08/13/02					No apparent change
22-04-09	BY-104	40	125	85		31	08/07/03		08/12/02					No apparent change
22-08-09	BY-108	40	80	40		36	07/12/07		08/07/02					No apparent change
22-09-07	BY-109	20	90	70		30	08/02/03		08/07/02					No apparent change
22-11-01	BY-111	40	101	61		15	07/12/07		08/07/02					No apparent change
22-11-09	BY-111	25	80	55		27	08/01/03		08/06/02					No apparent change
22-08-02	BY-108	25	103	78		74	01/26/03		12/13/01	07/30/02				No apparent change
22-08-05	BY-108	35	98	63	10	74	01/26/03		12/17/01	07/30/02				Apparent change 75-82 ft not confirmed
50-06-17	T-106	30	87	57		118	07/25/03	07/30/02	08/07/01					No apparent change; requires HRLS
22-07-02	BY-107	30	100	70	10	68	01/25/03		11/29/01	07/29/02				Apparent change 98-100 ft not confirmed
22-07-05	BY-107	30	97	67		68	01/25/03		12/12/01	07/29/02				Apparent change 75-81 ft not confirmed
50-06-04	T-106	55	93	68		118	07/24/03	07/29/02	07/23/01					No apparent change
50-06-06	T-106	65	120	95		130	07/24/03	07/29/02	07/24/01					No apparent change

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
50-06-08	T-106	46	120	109		130	07/24/03	07/29/02	07/25/01					No apparent change
22-06-05	BY-106	20	98	78		76	01/22/03		11/27/01	07/26/02				No apparent change
22-06-11	BY-106	40	80	40		26	06/30/07		07/26/02					No apparent change
50-06-05	T-106	30	116	86		130	07/21/03	07/26/02	08/06/01					No apparent change; requires HRLS
22-00-02	BY-103	40	99	59	10	63	01/21/03		11/15/01	07/25/02				No apparent change
50-01-04	T-101	20	123	103		37	07/19/03	07/24/02	08/07/01					No apparent change; requires HRLS
22-00-04	BY-102	40	99	59	10	31	07/18/03		07/23/02					No apparent change
22-02-01	BY-102	40	98	58		31	07/18/03		07/23/02					No apparent change
22-03-04	BY-103	40	101	61		63	01/19/03		11/15/01	07/23/02				Possible change 77-82 ft not confirmed
22-01-04	BY-101	20	90	70		29	07/17/03		07/22/02					No apparent change
22-10-07	BY-110	40	80	40		53	01/14/03		12/11/01	07/18/02				No apparent change
22-10-09	BY-110	40	80	40		22	06/22/07		07/18/02					No apparent change
60-12-01	U-112	35	125	60		37	07/12/03	07/17/02	11/06/01					No apparent change; requires HRLS
22-03-05	BY-103	20	99	83		50	07/11/03	07/16/02	12/20/01					No apparent change
10-05-09	A-105	45	77	32	10	115	06/26/03		06/26/01	07/01/02				No apparent change
22-04-11	BY-104	30	100	70	10	19	06/26/03		07/01/02					No apparent change
22-05-05	BY-105	40	80	40		25	06/05/07		07/01/02					No apparent change
21-02-04	BX-102	0	230	0		94	06/22/03	06/27/02	09/04/01					No apparent change; HRLS 6/27/02
10-00-04	A-103	45	85	40		12	05/30/07		06/25/02					No apparent change
10-03-01	A-103	45	125	80		12	05/30/07		06/25/02					No apparent change
10-01-01	A-101	45	85	40		89	06/16/03		06/27/01	06/21/02				No apparent change
10-01-03	A-101	45	78	33	10	89	06/16/03		06/27/01	06/21/02				No apparent change
10-01-04	A-101	35	85	50		114	06/16/03		06/27/01	06/21/02				No apparent change
10-05-05	A-105	45	74	29		115	06/15/03		06/25/01	06/20/02				No apparent change
10-05-07	A-105	45	75	30		115	06/15/03		06/26/01	06/20/02				No apparent change
10-05-08	A-105	45	55	10		115	06/15/03		06/26/01	06/20/02				No apparent change
10-05-10	A-105	25	100	75		140	06/15/03		06/26/01	06/20/02				No apparent change
10-05-12	A-105	45	75	30		115	06/15/03		06/26/01	06/20/02				No apparent change
10-01-28	A-101	20	43	23		114	06/13/03		06/19/01	06/18/02				No apparent change
10-01-39	A-101	20	44	24	10	114	06/13/03		06/20/01	06/18/02				No apparent change
10-00-06	A-103	45	85	40		12	05/23/07		06/18/02					No apparent change
10-05-02	A-105	45	119	74	10	115	06/13/03		06/25/01	06/18/02				No apparent change
10-01-16	A-101	20	52	32		114	06/12/03		06/19/01	06/17/02				No apparent change
11-01-02	AX-101	45	85	40		66	06/12/03		06/17/02					No apparent change
11-01-04	AX-101	45	85	40	10	66	05/22/07		06/17/02					No apparent change
11-01-01	AX-101	45	85	40		66	05/19/07		06/14/02					No apparent change
11-02-12	AX-102	20	50	30		30	06/09/03		06/14/02					No apparent change
11-03-02	AX-103	20	90	70		32	06/08/03		06/13/02					No apparent change
40-00-06	S-111	40	80	40		39	05/17/07		06/12/02					No apparent change
40-04-05	S-104	35	100	82		49	06/06/03	04/24/02	06/11/02					No apparent change
40-09-06	S-109	40	80	40	10	2	12/02/02		06/05/02					No apparent change; special request
40-11-09	S-111	40	80	40		39	05/31/03		06/05/02					No apparent change
40-12-02	S-112	40	80	40		12	12/02/02		06/05/02					No apparent change; special request
40-12-09	S-112	40	80	40		12	12/02/02		06/05/02					No apparent change; special request
40-12-04	S-112	40	80	40		12	12/01/02		06/04/02					No apparent change; special request

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
40-12-06	S-112	40	80	40		12	12/01/02		06/04/02					No apparent change; special request
40-12-07	S-112	40	80	40	10	12	12/01/02		06/04/02					No apparent change; special request
40-11-05	S-111	40	80	40	10	39	05/08/07		06/03/02					No apparent change
40-11-07	S-111	35	80	45		39	05/08/07		06/03/02					No apparent change
40-11-08	S-111	40	80	40		39	05/08/07		06/03/02					No apparent change
40-04-01	S-104	40	80	40		24	05/05/07		05/31/02					No apparent change
40-04-07	S-104	35	80	45		49	05/26/03		05/31/02					No apparent change
40-07-01	S-107	35	80	45		48	05/26/03		05/31/02					No apparent change
40-11-01	S-111	40	80	40		39	05/05/07		05/31/02					No apparent change
20-10-02	B-110	20	98	78		37	05/25/03		05/30/02					No apparent change; possible Sr-90 at 75 ft
20-10-09	B-110	35	75	40	10	12	05/04/07		05/30/02					No apparent change
20-00-05	B-101	35	110	75		39	05/24/03		05/29/02					No apparent change
20-01-06	B-101	25	60	35	10	39	05/24/03		05/29/02					No apparent change
20-10-07	B-110	35	75	40		37	05/24/03		05/29/02					No apparent change
20-01-01	B-101	35	75	40		39	05/23/03		05/28/02					No apparent change
20-06-03	B-106	35	75	40		33	05/23/03		05/28/02					No apparent change
20-07-05	B-107	35	80	45		26	04/27/07		05/23/02					No apparent change
20-07-08	B-107	35	80	45	10	13	04/27/07		05/23/02					No apparent change
20-07-11	B-107	35	85	50		38	05/18/03		05/23/02					No apparent change; possible Sr-90 at 72 ft
20-07-02	B-107	35	100	70		38	05/17/03		05/22/02					No apparent change
21-10-03	BX-110	0	100	0		41	05/16/03	05/21/02	08/30/01					No apparent change
21-07-06	BX-107	20	102	0		36	05/15/03	05/20/02	09/05/01					No apparent change
51-03-11	TX-103	40	100	60	10	30	11/16/02		05/20/02					Possible change 61-62 and 90-95 ft; freq. to 6 mos.
51-07-07	TX-107	40	85	55		29	05/15/03		05/20/02					No apparent change
51-04-02	TX-104	40	80	40		42	05/12/03		05/17/02					No apparent change
51-05-05	TX-105	40	80	40		64	11/13/02		05/17/02					No apparent change
51-05-07	TX-105	40	80	40	10	64	11/13/02		05/17/02					No apparent change
51-04-05	TX-104	40	98	58		54	11/12/02		05/16/02					No apparent change
51-04-06	TX-104	40	80	40	10	42	05/11/03		05/16/02					No apparent change
51-07-18	TX-107	40	80	40		29	05/11/03		05/16/02					No apparent change
51-05-01	TX-105	40	80	40		39	05/10/03		05/15/02					No apparent change
51-05-08	TX-105	40	80	40		33	04/19/07		05/15/02					No apparent change
51-05-10	TX-105	40	80	40		14	04/19/07		05/15/02					No apparent change
51-07-09	TX-107	40	100	60	10	23	04/19/07		05/15/02					No apparent change
51-03-12	TX-103	40	100	60		30	05/09/03		05/14/02					No apparent change
52-03-03	TY-103	40	80	61		30	05/09/03	05/13/02	05/14/02					No apparent change; HRLS 05/13/02
51-01-02	TX-101	40	80	40	10	41	05/08/03		05/13/02					No apparent change
51-03-01	TX-103	40	80	40		30	05/08/03		05/13/02					No apparent change
51-03-09	TX-103	40	98	58		55	11/09/02		05/13/02					No apparent change
51-05-03	TX-105	25	80	55		51	05/08/03		05/13/02					No apparent change
51-10-01	TX-110	35	95	60		21	04/13/07		05/09/02					No apparent change
51-10-13	TX-110	25	97	72		21	04/13/07		05/09/02					No apparent change
51-10-25	TX-110	40	98	58	10	21	04/13/07		05/09/02					No apparent change
51-15-04	TX-115	20	80	60		23	04/13/07		05/09/02					No apparent change
52-06-05	TY-106	40	148	108		67	08/06/02		05/08/02					Possible change 130-148 ft

Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
52-06-02	TY-106	40	65	25		17	05/02/03		05/07/02					No apparent change
52-06-04	TY-106	40	80	40	10	54	05/02/03		05/07/02					No apparent change
52-06-06	TY-106	40	100	60		54	05/02/03		05/07/02					No apparent change
52-06-07	TY-106	200	238	38		42	05/02/03		05/07/02					No apparent change; Co-60 may be in GW
52-03-12	TY-103	40	100	60		30	04/27/03		05/02/02					No apparent change
52-05-07	TY-105	40	96	56		82	10/29/02		05/02/02					No apparent change
30-01-09	C-101	20	70	55	10	43	04/20/03		04/25/02					No apparent change
30-05-07	C-105	30	48	11		31	04/20/03		04/25/02					No apparent change; requires HRLS
40-02-03	S-102	20	80	0		39	04/20/03	04/25/02						HRLS 04/25/02; no apparent change
30-00-01	C-106	30	67	37		38	04/19/03		04/24/02					No apparent change
30-06-12	C-106	10	100	90		50	07/23/02		04/24/02					No apparent change
30-06-10	C-106	30	129	99		63	07/22/02		04/23/02					Possible change 124-126 ft Co-60
30-09-06	C-109	30	98	68	15	42	07/22/02		04/23/02					No apparent change
41-12-02	SX-112	40	122	0		63	04/18/03	04/23/02	10/03/01					No apparent change; HRLS 04/23/02
30-05-02	C-105	30	90	60		31	04/17/03		04/22/02					No apparent change
30-05-04	C-105	30	118	88	10	31	04/17/03		04/22/02					No apparent change
30-05-08	C-105	30	49	19	14	31	04/17/03		04/22/02					No apparent change
30-06-09	C-106	25	80	55	10	50	04/17/03		04/22/02					No apparent change
41-09-03	SX-109	40	74	0		46	04/17/03	04/22/02	09/26/01					No apparent change; HRLS 04/22/02
41-09-07	SX-109	40	73	35		58	10/19/02	04/22/02	10/03/01	04/05/02				No apparent change; HRLS 04/22/02
30-03-09	C-103	30	98	68	15	54	04/14/03		04/19/02					No apparent change
30-05-03	C-105	30	90	60		31	04/14/03		04/19/02					No apparent change
41-07-05	SX-107	40	75	0		42	04/14/03	04/19/02	09/25/01					No apparent change; HRLS 04/19/02
41-07-07	SX-107	40	75	26		54	10/16/02	04/19/02	09/26/01	04/09/02				No apparent change; HRLS 04/19/02
30-01-01	C-101	30	70	40		31	03/23/07		04/18/02					No apparent change
30-01-06	C-101	30	70	40		43	04/13/03		04/18/02					No apparent change
30-00-03	C-102	30	70	40		37	03/23/07		04/18/02					No apparent change
41-08-07	SX-108	40	65	0		52	04/13/03	04/18/02	09/25/01					No apparent change; HRLS 04/18/02
41-08-11	SX-108	40	75	0		40	04/13/03	04/18/02	09/26/01					No apparent change; HRLS 04/18/02
41-11-10	SX-111	40	95	69		53	10/15/02	04/18/02	09/25/01	04/09/02				No apparent change; HRLS 04/18/02
30-05-05	C-105	30	98	68		31	04/12/03		04/17/02					No apparent change
41-09-09	SX-109	40	95	66		58	10/02/02		10/03/01	04/05/02				No apparent change
41-14-06	SX-114	30	76	46		31	03/28/03		04/02/02					No apparent change
41-14-09	SX-114	40	75	35		31	03/28/03		04/02/02					No apparent change
41-14-11	SX-114	40	75	35	10	31	03/28/03		04/02/02					No apparent change
41-10-01	SX-110	40	80	40		54	09/28/02		09/13/01	04/01/02				No apparent change
41-12-04	SX-112	40	85	45	10	26	03/06/07		04/01/02					No apparent change
41-12-06	SX-112	40	73	33		26	03/06/07		04/01/02					No apparent change
41-09-06	SX-109	40	74	34		27	03/02/07		03/28/02					No apparent change
41-09-11	SX-109	40	74	34		27	03/02/07		03/28/02					No apparent change
41-10-11	SX-110	45	75	30		23	03/02/07		03/28/02					No apparent change
41-02-05	SX-102	40	80	40		32	03/01/07		03/27/02					No apparent change
41-08-03	SX-108	40	75	35		34	03/01/07		03/27/02					No apparent change
41-08-06	SX-108	40	80	40		34	03/01/07		03/27/02					No apparent change
41-09-02	SX-109	40	74	34		33	03/22/03		03/27/02					No apparent change

Appendix A. Boreholes Monitored During FY 2002

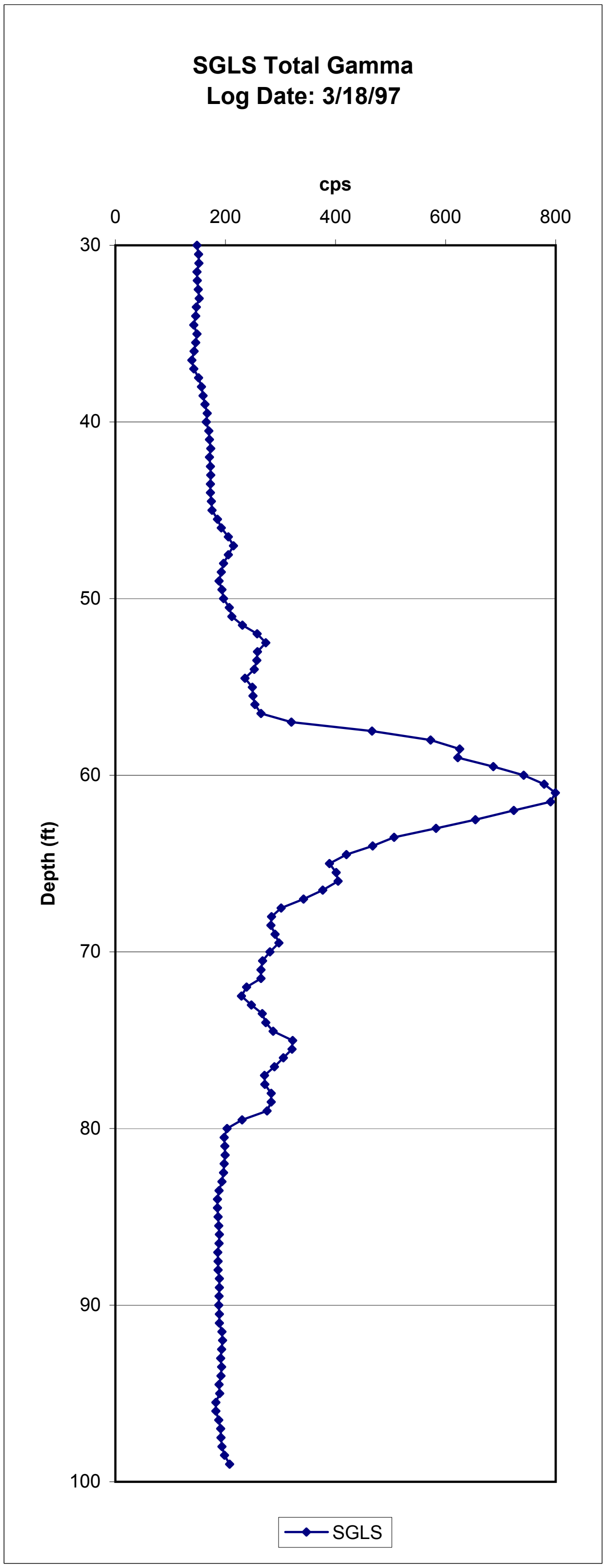
Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
41-02-07	SX-102	40	80	40		32	02/28/07		03/26/02					No apparent change
41-03-02	SX-103	30	80	50		45	03/21/03		03/26/02					No apparent change
41-03-05	SX-103	40	80	40		45	03/21/03		03/26/02					No apparent change
21-01-01	BX-101	15	99	89		33	03/20/03		03/25/02					No apparent change
21-06-05	BX-106	25	75	55		26	03/20/03		03/25/02					No apparent change
21-11-03	BX-111	35	99	69		32	03/20/03		03/25/02					No apparent change
21-11-04	BX-111	35	75	45		32	03/16/03		03/21/02					No apparent change
21-00-21	BX-111	35	90	55		32	03/15/03		03/20/02					No apparent change
21-00-22	BX-111	20	73	53		32	03/15/03		03/20/02					No apparent change
21-11-05	BX-111	35	75	40		32	03/15/03		03/20/02					No apparent change
21-11-07	BX-111	35	75	40		32	03/15/03		03/20/02					No apparent change
21-05-06	BX-105	35	100	65		28	03/14/03		03/19/02					No apparent change
21-08-06	BX-107	35	75	40		24	02/21/07		03/19/02					No apparent change
21-08-05	BX-108	30	80	50		16	02/21/07		03/19/02					No apparent change
21-08-07	BX-108	30	100	70		28	03/14/03		03/19/02					No apparent change
21-00-09	BX-111	35	73	38		32	03/14/03		03/19/02					No apparent change
21-04-04	BX-104	20	75	55		2	02/20/07		03/18/02					No apparent change
21-04-06	BX-104	20	75	55		2	02/20/07		03/18/02					No apparent change
21-04-11	BX-104	35	97	62		27	03/13/03		03/18/02					No apparent change
21-05-05	BX-105	35	99	64		28	03/13/03		03/18/02					No apparent change
21-00-05	BX-101	35	125	90		33	03/09/03		03/14/02					No apparent change
21-03-07	BX-103	35	80	45		16	02/16/07		03/14/02					No apparent change
21-01-02	BX-101	35	98	63		33	03/08/03		03/13/02					No apparent change
21-03-05	BX-103	35	80	45		29	02/20/03		02/25/02					No apparent change
21-03-11	BX-103	35	75	40		16	01/30/07		02/25/02					No apparent change
50-07-03	T-107	30	70	40		29	01/02/07		01/28/02					No apparent change
50-00-05	T-110	30	70	40		20	12/29/06		01/24/02					No apparent change
50-02-02	T-102	30	70	40		24	01/17/03		01/22/02					No apparent change
50-04-07	T-104	20	70	50		23	01/16/03		01/21/02					No apparent change
50-02-09	T-102	30	85	55		30	01/11/03		01/16/02					No apparent change
50-08-09	T-108	30	100	70		27	01/11/03		01/16/02					No apparent change
50-02-08	T-103	30	85	55		28	01/09/03		01/14/02					No apparent change
50-03-04	T-103	20	120	100		28	01/09/03		01/14/02					No apparent change
50-03-05	T-103	30	120	90		28	01/09/03		01/14/02					No apparent change
50-08-07	T-108	30	119	89		27	01/05/03		01/10/02					No apparent change
50-09-05	T-109	30	90	60		29	01/05/03		01/10/02					No apparent change
50-11-10	T-111	30	80	50		19	12/15/06		01/10/02					No apparent change
50-09-09	T-109	30	70	40		23	12/14/06		01/09/02					No apparent change
50-05-07	T-105	30	87	57		27	01/03/03		01/08/02					No apparent change
50-08-08	T-108	30	95	65		27	01/03/03		01/08/02					No apparent change
50-08-19	T-108	30	86	56		27	01/03/03		01/08/02					No apparent change
60-00-02	U-101	35	75	40		27	12/12/06		01/07/02					No apparent change
60-08-10	U-108	35	75	40		19	12/12/06		01/07/02					No apparent change
60-08-08	U-108	35	75	40		19	12/08/06		01/03/02					No apparent change
60-08-09	U-108	35	75	40		19	12/08/06		01/03/02					No apparent change

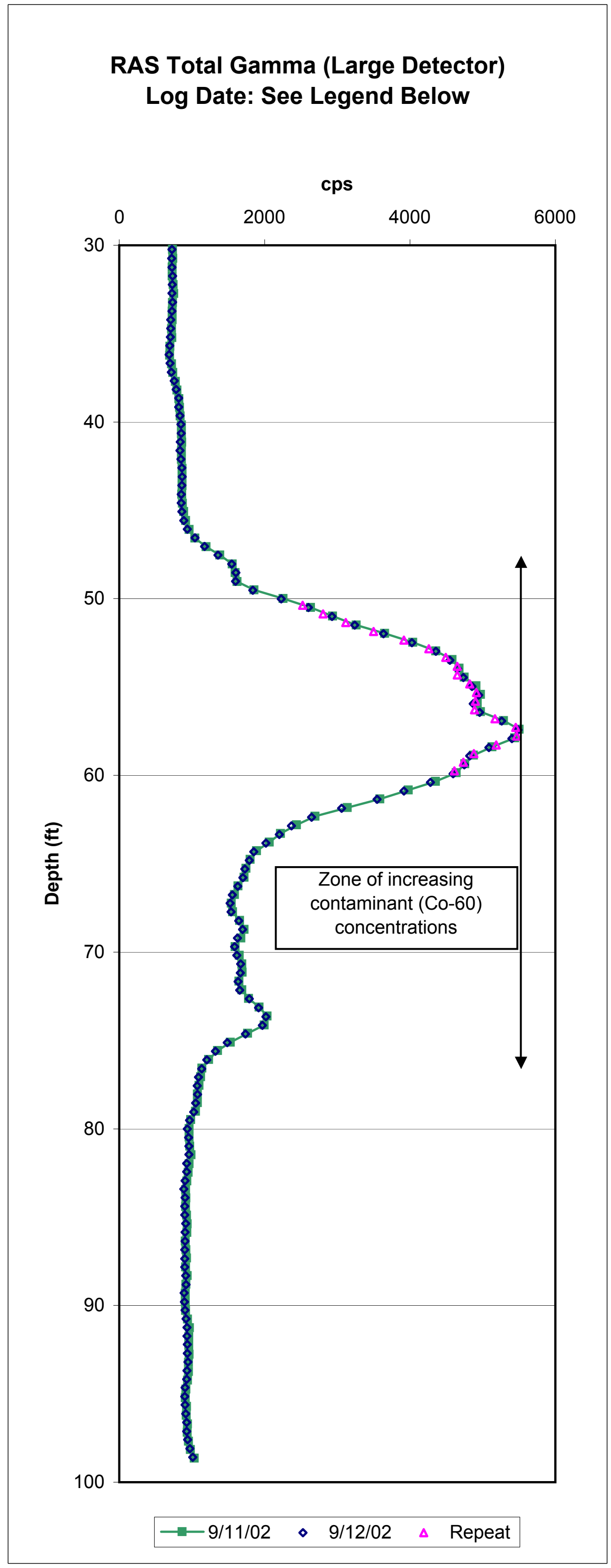
Appendix A. Boreholes Monitored During FY 2002

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
60-01-08	U-101	35	75	40		27	12/07/06		01/02/02					No apparent change
60-01-10	U-101	35	75	40		27	12/07/06		01/02/02					No apparent change
22-06-09	BY-106	40	97	57		39	11/23/06		12/19/01					No apparent change
22-07-09	BY-107	20	99	84		55	12/14/02		12/19/01					No apparent change
22-08-07	BY-108	40	100	60		49	12/12/02		12/17/01					No apparent change
22-08-01	BY-108	25	99	74		61	12/09/02		12/14/01					No apparent change
22-08-06	BY-108	40	99	59		61	12/09/02		12/14/01					No apparent change
22-10-05	BY-110	40	99	59		41	12/06/02		12/11/01					No apparent change
22-07-01	BY-107	40	98	58		43	12/01/02		12/06/01					No apparent change
22-06-07	BY-106	35	132	97		64	11/23/02		11/28/01					No apparent change
22-06-01	BY-106	40	80	40		51	11/22/02		11/27/01					No apparent change
22-03-07	BY-103	40	99	59		38	11/21/02		11/26/01					No apparent change
22-03-09	BY-103	30	98	68		38	11/21/02		11/26/01					No apparent change
22-00-03	BY-103	40	146	106		50	11/14/02		11/19/01					No apparent change
22-03-08	BY-103	40	99	59		38	11/14/02		11/19/01					No apparent change
22-03-06	BY-103	40	101	61		38	11/11/02		11/16/01					No apparent change
22-05-01	BY-105	40	98	58		62	11/09/02		11/14/01					No apparent change
22-05-09	BY-105	40	98	58		62	11/09/02		11/14/01					No apparent change
60-11-12	U-111	35	75	40		37	10/31/02		11/05/01					No apparent change
60-11-07	U-111	35	75	40		37	10/20/02		10/25/01					No apparent change
41-12-03	SX-112	40	76	41		63	09/28/02		10/03/01					No apparent change

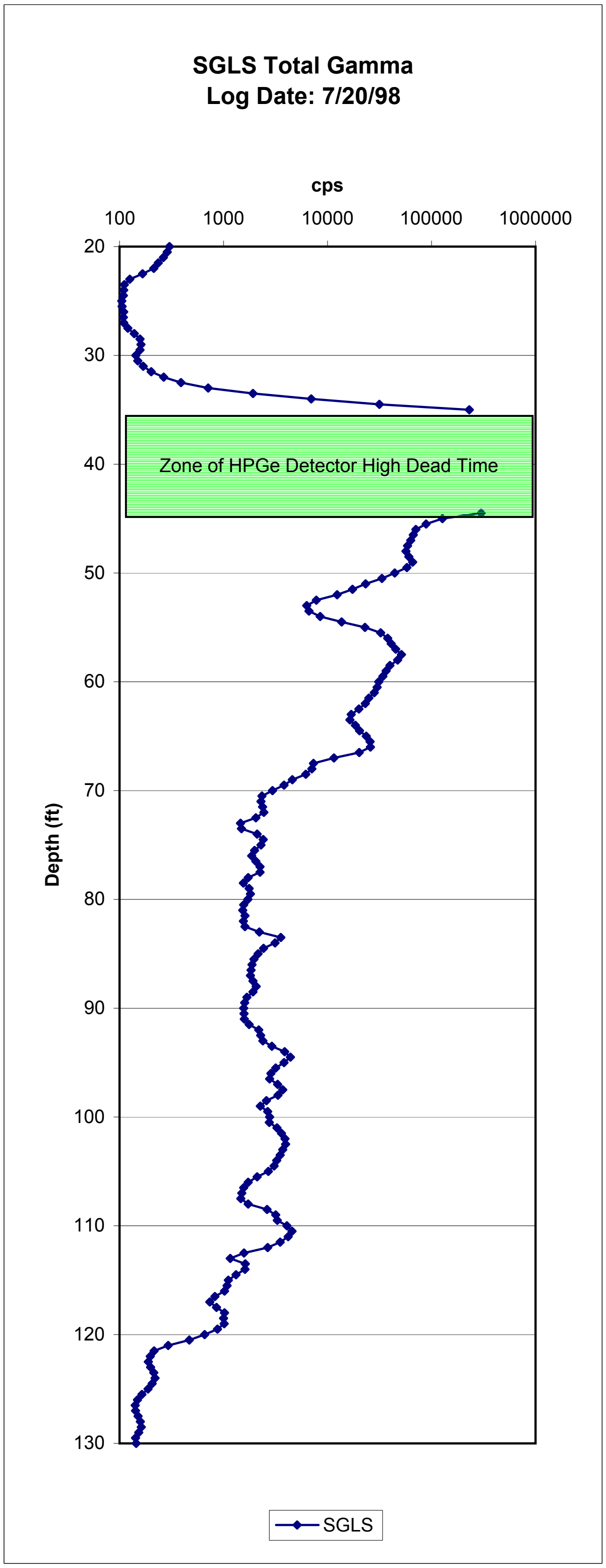
Appendix B
Comparison of RAS and SGLS Baseline Measurements of Boreholes Identified in the Fourth Quarter of FY 2002 That Suggest Contaminant Movement

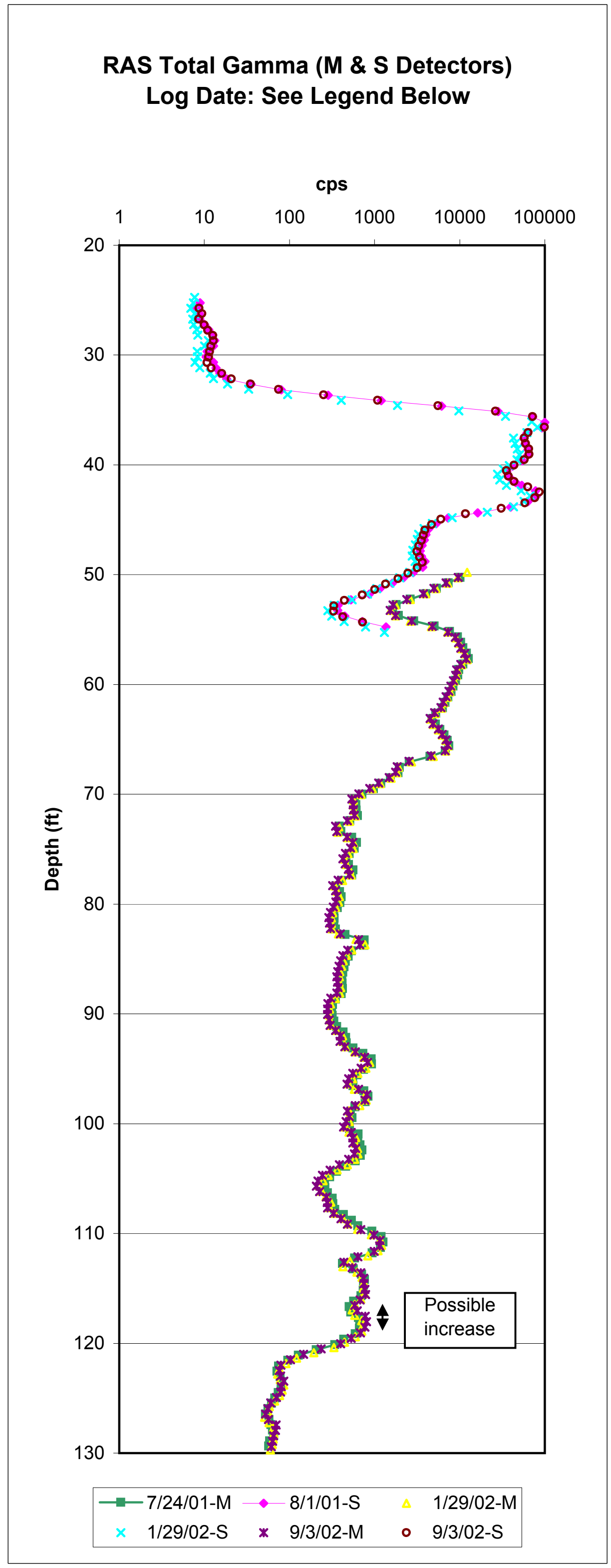
Borehole 30-08-02



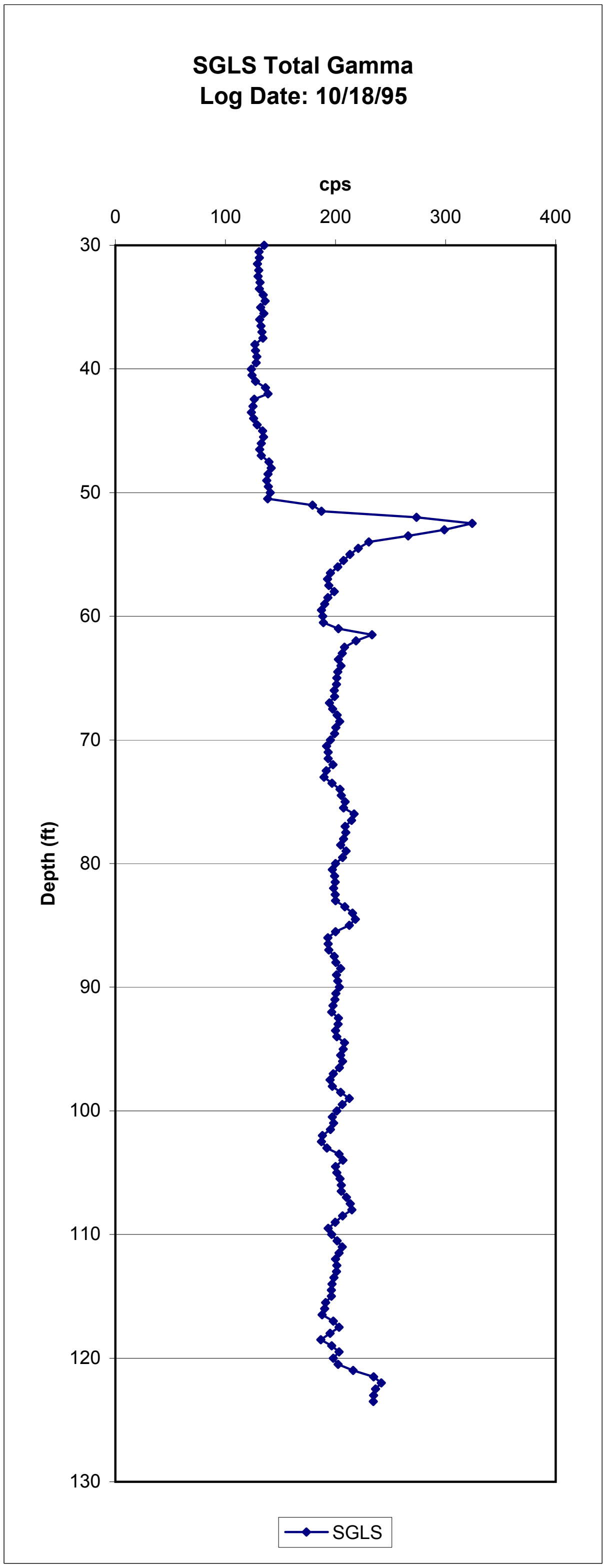


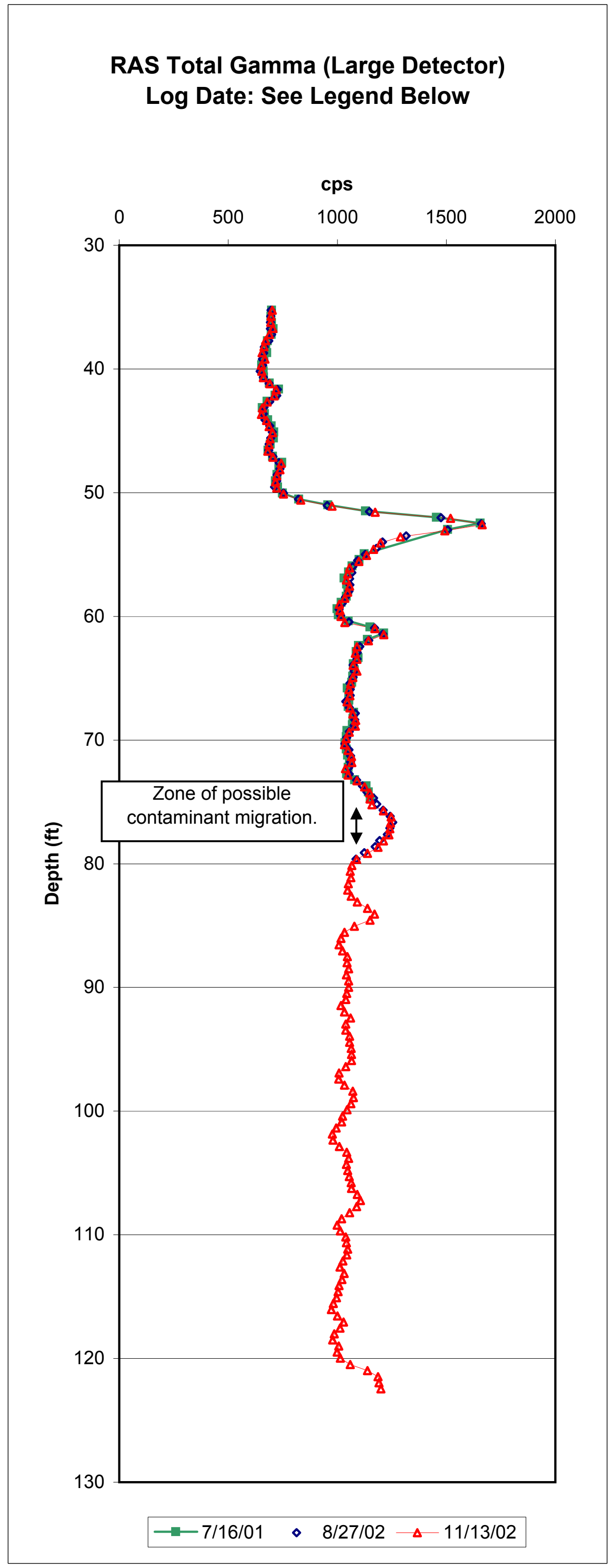
Borehole 50-06-18





Borehole 60-05-05





Appendix C
Anomaly in Borehole 30-08-02

Anomaly in Borehole 30-08-02
RG McCain 9/17/2002

On September 11, 2002, RAS logging in borehole 30-08-02 (C Tank Farm) detected a possible anomaly which may indicate recent contaminant migration. A repeat log run with the RAS was made on September 12, yielding the same result. Attached are copies of the total gamma logs for the SGLS baseline data (3/18/97) and the RAS large detector. The first plot shows a side-by-side plot. The second plot shows the SGLS total counts scaled to provide values comparable to the RAS response. Comparison of the two logs indicates an increase in gamma activity at approximately 47 to 61 ft, and also at 67 to 75 ft. Evaluation of window counts and RAS spectra indicate the primary source of the anomaly is ^{60}Co.

SGLS baseline data for 30-08-02 (March, 1997) indicate ^{137}Cs and ^{154}Eu occurring at approximately 21 ft, with maximum concentrations of about 1000 pCi/g ^{137}Cs and about 20 pCi/g ^{154}Eu. ^{60}Co is detected from 46.5 to 79.5 ft, with a maximum concentration of approximately 10 pCi/g at 61 ft.

The 241-C Tank Farm Addendum shows a ^{60}Co plume originating between tanks C-108 and C-109, and extending downward and eastward. This plume is attributed to the cascade line between C-108 and C-109. The evidence of movement previously observed in borehole 30-06-10 (ref MACTEC letter to John Silko, Mar 10, 1999) appears to be part of the same contaminant plume. The presence of anomalies in both 30-08-02 and 30-06-10 suggests active contaminant migration may be occurring in a plume originating between C-108 and C-109, and extending downward and eastward under tank C-106. Although the plume does not appear to originate from C-106, it could impact the accelerated closure program.

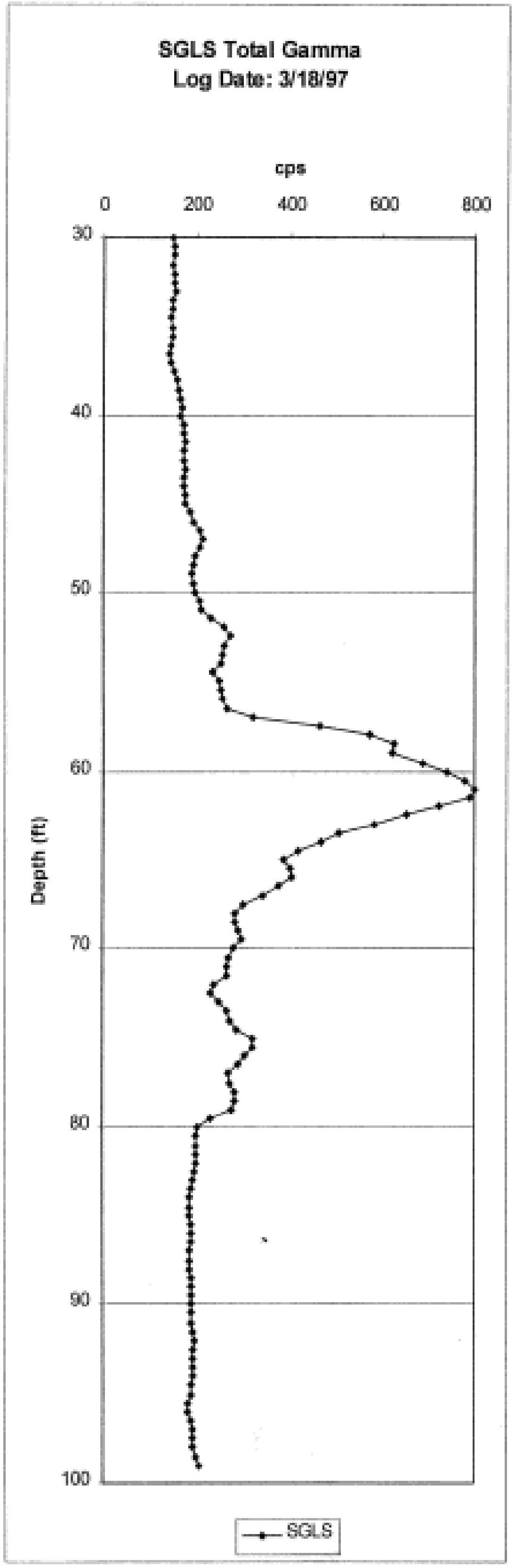
There are two drywells between 30-08-02 and 30-06-10. 30-09-07 was also logged with the RAS on September 11. Comparison of this data with 1997 SGLS baseline data indicate a possible anomaly at 68 to 80 ft. This is more subtle, and was not noticed in the initial comparison. Borehole 30-09-06 was logged with the RAS on April 23, 2002. Comparison with 1997 SGLS baseline data does not indicate any anomaly, although the presence of equivalent total count rate at 77 to 86 ft is suspicious, since the primary contaminant in this interval is ^{60}Co, with a half life of 5.27 years.

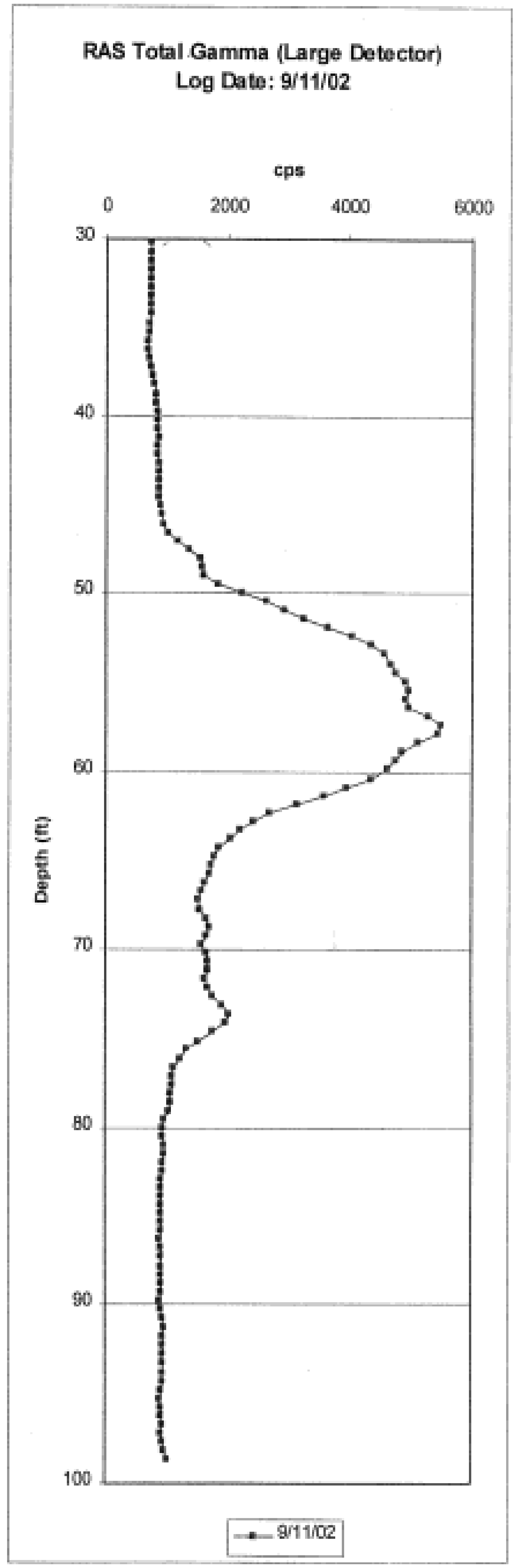
According to Hanlon (June 31, 2002), both C-108 and C-109 are designated as sound. Interim stabilization for C-108 was completed in March, 1984, and C-109 was interim stabilized in November, 1983. Both tanks are listed as "administratively stabilized." C-108 is reported to contain 66 Kgal sludge, and C-109 is reported to contain 63 Kgal sludge. Both tanks are reported to contain 4 Kgal drainable interstitial liquid.

Historical gross gamma data from 30-08-02 suggest a similar episode of contaminant movement may have occurred between 1980 and 1985.

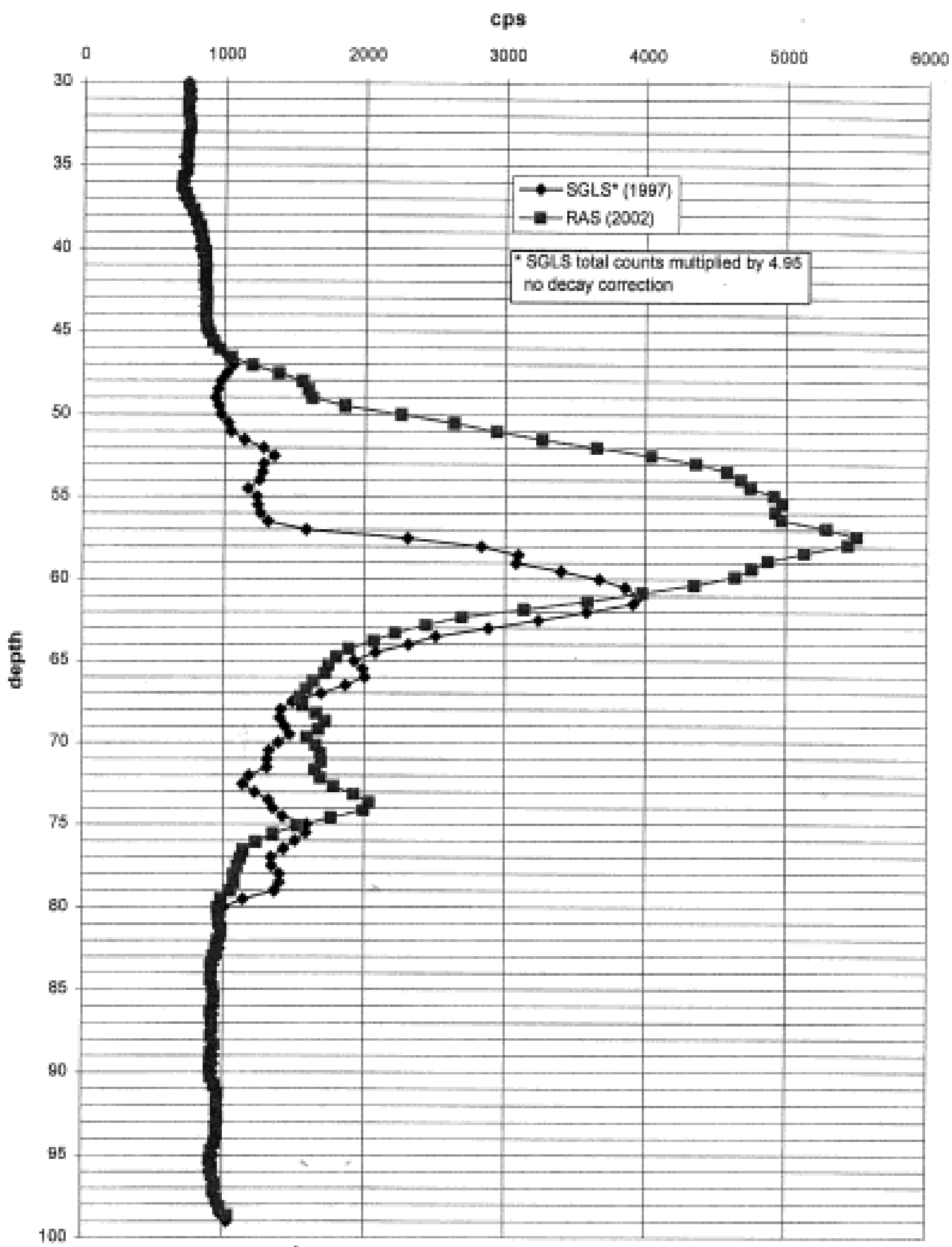
Stoller is continuing to evaluate available data, and will develop recommendations for additional work.

Borehole 30-08-02





30-08-02 RAS vs SGLS (Total Cts)



Appendix D
Preliminary Evaluation of Log Data in the Vicinity of Tank U-107

Preliminary Evaluation of Log Data in the Vicinity of Tank U-107

Letter Report

Author: Paul Henwood
Date: November 1, 2001

Purpose and Scope:

This report provides a brief summary of available geophysical logging data in the vicinity of tank U-107 (U Tank Farm) as of July 2001. It also provides recommendations for future work to investigate continuing contaminant migration and to assess the impact of waste retrieval operations in tank U-107.

Introduction:

Geophysical logging was conducted in the U Tank Farm during June and July 2001. Logging was conducted according to a strategy developed in the *Hanford Tank Farms Vadose Zone Monitoring Project Baseline Monitoring Plan* (DOE 2001) and in response to a special request to monitor boreholes in the area of tank U-107 in support of waste retrieval operations.

The purpose of the Hanford Tank Farms Vadose Zone Monitoring Project (VZMP) is to periodically monitor vadose zone gamma activity in selected depth intervals within existing monitoring boreholes adjacent to single-shell tanks. Gamma activity is compared to activity detected during the baseline characterization of the same boreholes conducted between 1995 and 2000 to detect any changes. Monitoring frequency is determined on the basis of existing contamination levels, plume behavior, tank characteristics, and tank farm operational requirements. This routine monitoring is conducted using a thallium-activated sodium-iodide (NaI[Tl]) detection system referred to as the Radionuclide Assessment System (RAS). Additional characterization may be required in selected boreholes using germanium detection systems that were used to develop the baseline characterization of the tank farm boreholes. These systems are referred to as the Spectral Gamma Logging System (SGLS) and High Rate Logging System (HRLS).

The special request was prompted by findings of the baseline characterization where the SGLS data indicated a processed uranium contaminant plume in the vicinity of tanks U-104 and U-107 may be continuing to migrate. Because it had been two years since the last log data were collected in boreholes in the area of the plume, it was deemed necessary to document any changes in the contaminant levels prior to the initiation of waste retrieval operations in tank U-107. To accomplish this task, a combination of logging using the RAS and SGLS was performed in specified boreholes. All boreholes in the vicinity of tank U-107 were logged with the RAS to provide a basis against which subsequent RAS logs can be compared to detect future contaminant movement. In addition, selected borehole intervals on the north side of tank U-107 were relogged with the SGLS to detect changes in the baseline indicative of ongoing movement. Sufficient data would then be collected using the RAS during and after waste retrieval to attempt to segregate any increases in contaminants that may be related to retrieval operations from increases that have occurred from past waste releases associated with tank U-104.

The purpose of this preliminary data report is to summarize vadose zone data collected in the vicinity of tank U-107 up to July 2001, and provide recommendations for future logging in the U Tank Farm as it relates to the routine monitoring and the special request logging. A final data report containing a complete analysis and interpretation will be provided after waste retrieval operations and follow up logging have been completed.

Summary of Available Data:

Table 1 and Figure 1 summarize data collection activities in U Tank Farm during June and July 2001 in support of the routine VZMP and the special request.

Table 1. Summary of Borehole Data Collected in the U Tank Farm During July 2001

Borehole	SGLS Data Interval (ft)	SGLS Data Date	Score	RAS Data Interval (ft)	RAS Data Date	Next Log Date	Comments
60-07-01	0-98.5	11/95	88	40-98.5	06/01	10/01	Special study; movement detected
	20-93	05/99					
	50-85	07/01					
60-07-02	0-126	11/95	56	35-100	06/01	10/01	Special study
60-10-01	0-125.5	11/95	16	40-60	06/01	10/01	Special study
60-10-11	0-98.5	11/95	16	40-60	06/01	10/01	Special study
60-08-04	0-127.5	11/95	57	35-100	06/01	10/01	Special study
	50-70	04/99					
60-07-10	0-98.5	11/95	88	40-98.5	06/01	10/01	Special study; movement detected
	50-80	04/99					
	20-98.5	07/01					
60-07-11	0-124	11/95	88	40-100	06/01	10/01	Special study; movement detected
	50-95	05/99					
	20-102	07/01					
60-04-03	0-125.5	09/95	44	35-75	07/01	06/06	
60-04-08	0-118.5	09/95	82	40-90	07/01	10/01	Movement detected
	50-85	04/99					
60-04-10	0-118	09/95	69	35-90	07/01	07/02	
60-04-12	0-125	09/95	44	35-75	07/01	06/06	
60-05-04	0-72.5	10/95	49	35-72.5	07/01	10/01	Near movement
60-05-05	0-123.5	05/96	49	35-75	07/01	07/02	
60-10-07	0-121	12/95	41	35-75	07/01	07/02	
	51-59	12/99					

Most of the boreholes logged would have been selected using the monitoring plan selection criteria (DOE 2001), where the total score is used to prioritize boreholes. The total score is derived on the basis of borehole and plume characteristics, proximity of a borehole to a suspected leaking tank, and on the volume of drainable liquid currently stored in a tank. The total score is a relative measure of the overall likelihood for measurements to detect movement in the vadose zone. Boreholes with total scores in excess of 37 were selected for routine monitoring during calendar year 2001. In five cases a borehole selected for routine monitoring was also designated for logging as a result of the special study request. Two boreholes were logged for the special request even though the total score was low and would not have been scheduled for logging until the following year.

All boreholes were logged using the RAS and three boreholes were also logged with the SGLS. Four boreholes indicated apparent changes. Measurements with the SGLS in boreholes 60-07-01, 60-07-10, and 60-07-11 corroborated continued change as suggested in the U Tank Farm addendum (DOE 2000), where 1999 measurements showed intervals of uranium-238 (^{238}U) and uranium-235 (^{235}U) contamination extending to greater depths than in the 1995 baseline. The 2001 SGLS and RAS measurements for these three boreholes shown in Figures 2-4 suggest continuing downward contaminant migration.

Borehole 60-04-08 was selected for routine monitoring with the RAS but was not included in the special study. Total gamma measurements in this borehole indicate the possibility of movement relative to the 1995 baseline SGLS total gamma (Figure 5). The 1999 SGLS measurements did not extend deep enough to detect potential contaminant migration. This borehole was not logged with the SGLS in 2001.

Randall and Price (2001) provided a summary of historical gross gamma ray data collected in U Tank Farm boreholes for the purpose of determining trends of gamma activity over time. Of the boreholes included in Table 1, only data acquired from borehole 60-07-11 indicate current instability; the instability is shown for a depth interval from 48 to 94 ft. The historical data and the methodology used to evaluate activity in the boreholes are not sufficient to detect movement for low levels of observed contamination.

Conclusions:

Preliminary evaluation of data suggest the following:

- Observed contaminant migration is not related to ongoing work in tank U-107.
- Downward migration of ^{238}U and ^{235}U contamination has occurred since at least 1995.
- Contamination is probably related to a known leak from tank U-104.

Recommendations:

Figure 6 summarizes all RAS data collected for the special request investigation and shows the intervals of potential contaminant movement on the basis of SGLS comparisons or in the case of borehole 60-04-08, on the basis of an SGLS/RAS comparison. Future logging in the U Tank Farm will be conducted with the RAS and direct comparisons will be made using the total gamma count rate.

It is recommended that all seven boreholes selected for special study be placed on a routine quarterly logging frequency using the RAS. This logging will be coordinated with CHG to avoid interference with waste retrieval operations. In addition, boreholes 60-04-08 and 60-05-04 should be added to the special study boreholes and be logged quarterly with the RAS. The remainder of boreholes shown in Table 1 will be logged with a frequency consistent with the strategy set forth in the baseline monitoring plan (DOE 2001).

In addition to the special request boreholes scheduled for logging, boreholes 60-11-07, 60-11-12, and 60-12-01 will also be logged during October 2001 for purposes of routine monitoring unrelated to the special request.

The historical gross gamma data from selected boreholes should be evaluated in further detail to identify the time of initial contaminant movement.

Neutron moisture logging should be implemented in boreholes associated with the special request because moisture is the most likely driving mechanism for contaminant migration.

References:

McCain, R.G., 2001. Letter to D. Baide, CH2M Hill Hanford Group (CHG), Subject: "Geophysical Logging in Support of Waste Retrieval at Tank U-107," April 24, 2001, MACTEC-ERS, Richland, Washington.

Randall, R., and R. Price, 2001. *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-U Tank Farm-200 West,* RPP-7729, Rev. 0, prepared by Three Rivers Scientific, Richland, Washington.

U.S. Department of Energy (DOE), 1996. *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Summary Data Report for Tank U-107*, GJ-HAN-36, prepared by Rust Geotech for the Grand Junction Projects Office, Grand Junction, Colorado.

_________, 2000. *Hanford Tank Farms Vadose Zone, Addendum to the U Tank Farm Report,* GJO-97-1-TARA, GJO-HAN-8, prepared by MACTEC-ERS for the Grand Junction Office, Grand Junction, Colorado.

U.S. Department of Energy (DOE), 2001. *Hanford Tank Farms Vadose Zone Monitoring Project*, *Baseline Monitoring Plan,* MAC-HGLP 1.8.1, Revision 0, prepared by MACTEC-ERS for the Grand Junction Office, Grand Junction, Colorado.

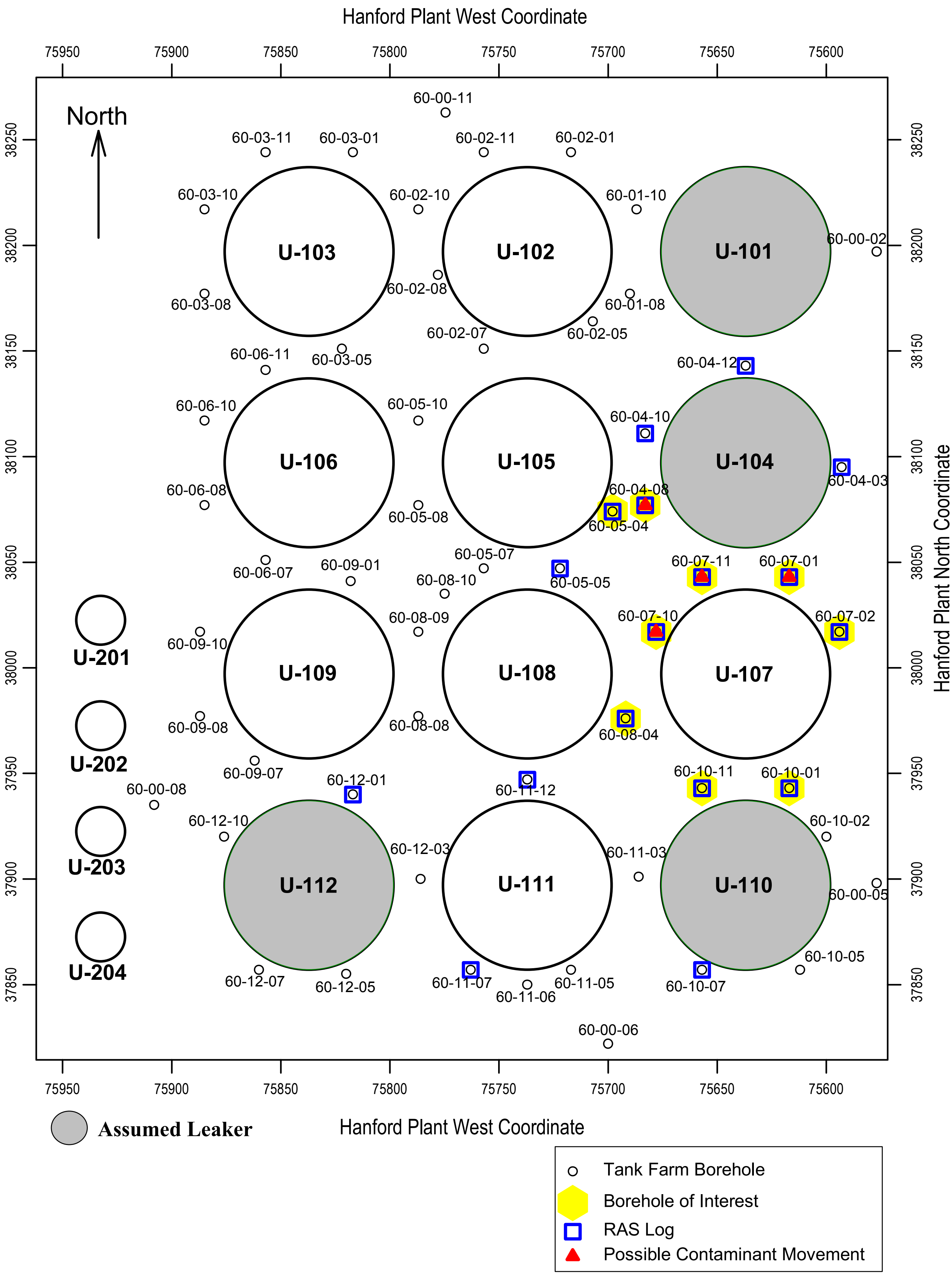

Hanford Plant West Coordinate
North
U-103
U-102
U-101
U-106
U-105
U-104
U-109
U-108
U-107
U-112
U-111
U-110
U-201
U-202
U-203
U-204
Hanford Plant North Coordinate
Assumed Leaker
Tank Farm Borehole
Borehole of Interest
RAS Log
Possible Contaminant Movement

Figure 1

60-07-01
Comparison of SGLS and RAS Data

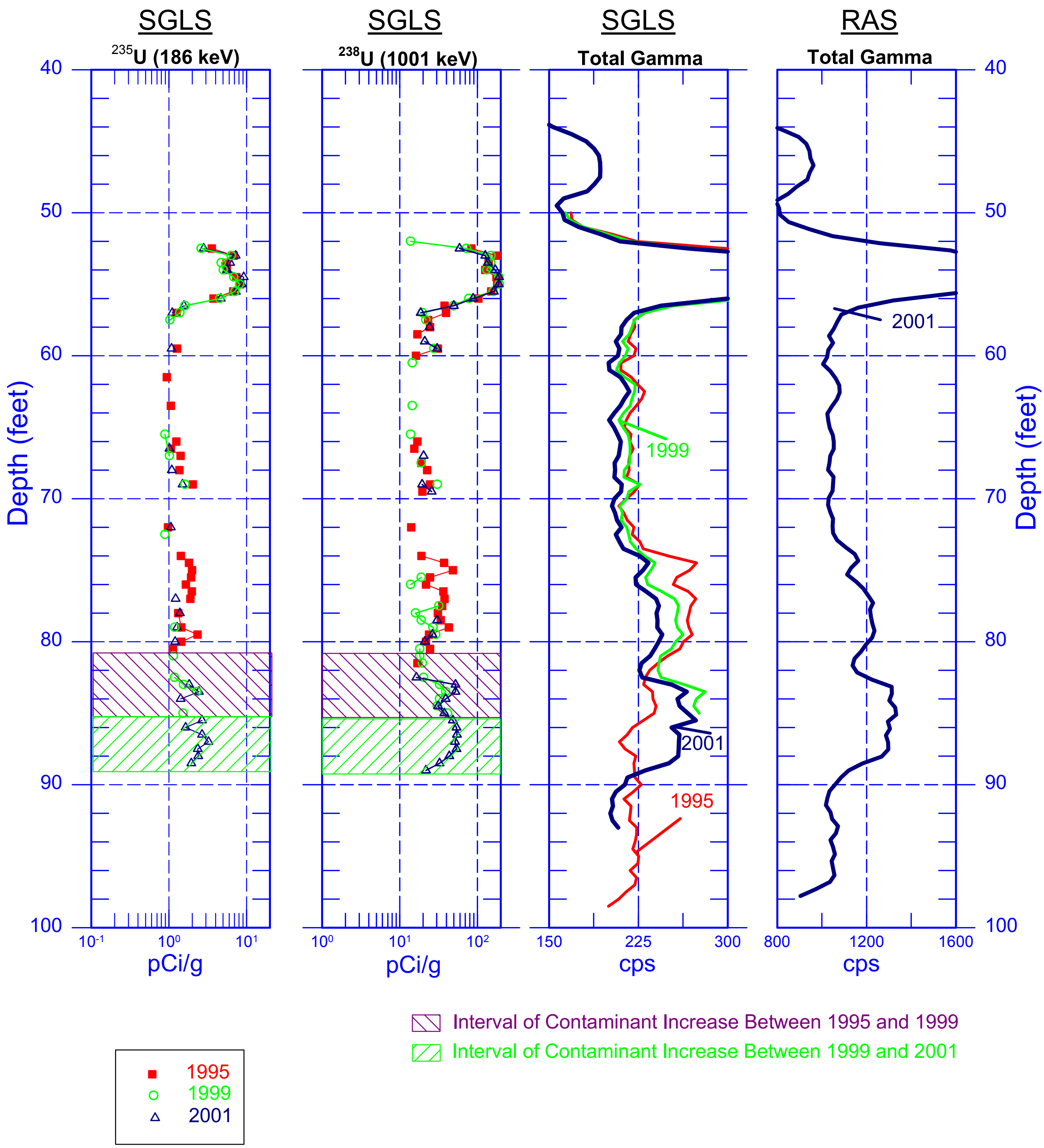


Figure 2

60-07-10
Comparison of SGLS and RAS Data

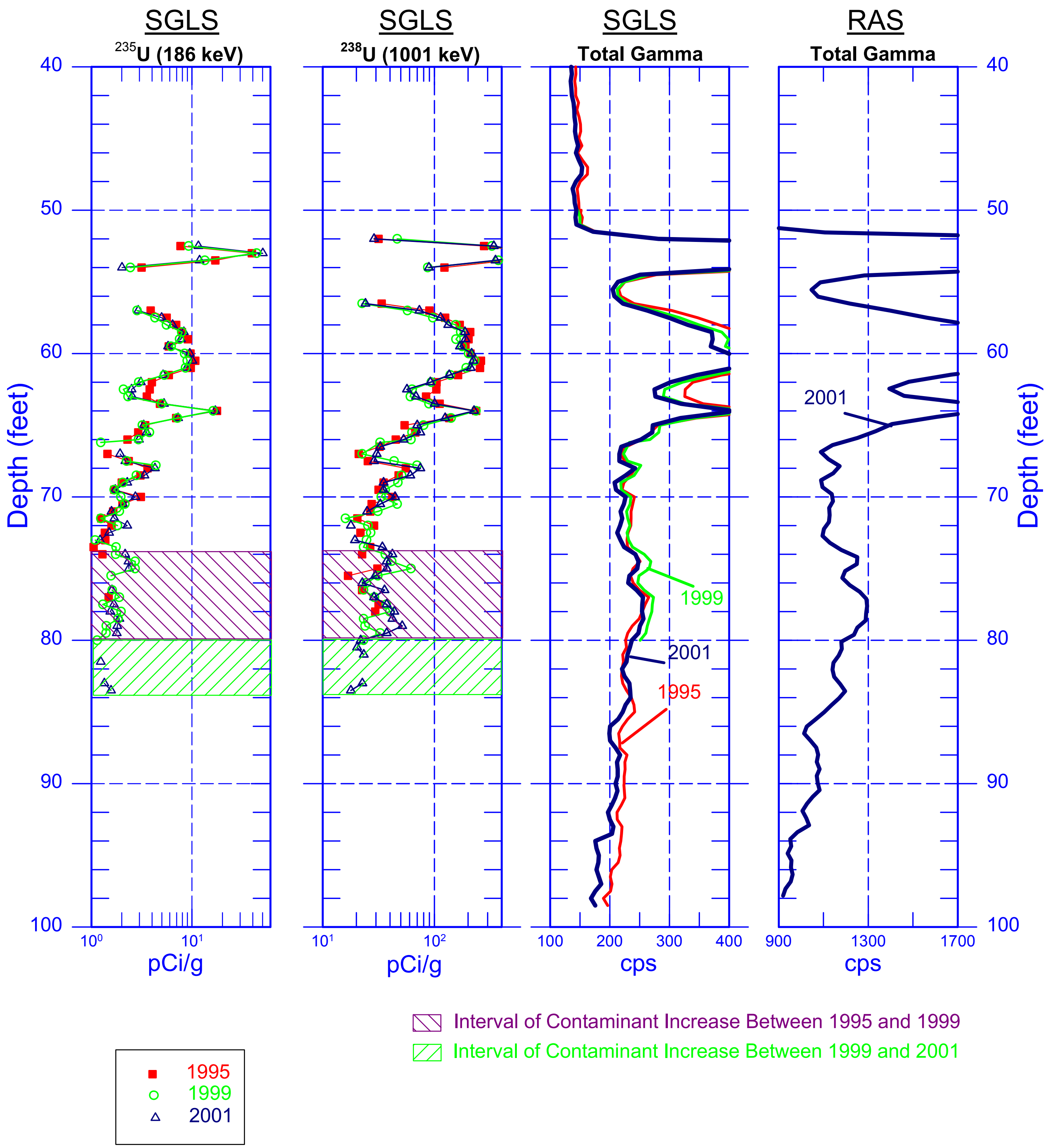


Figure 3

60-07-11
Comparison of SGLS and RAS Data

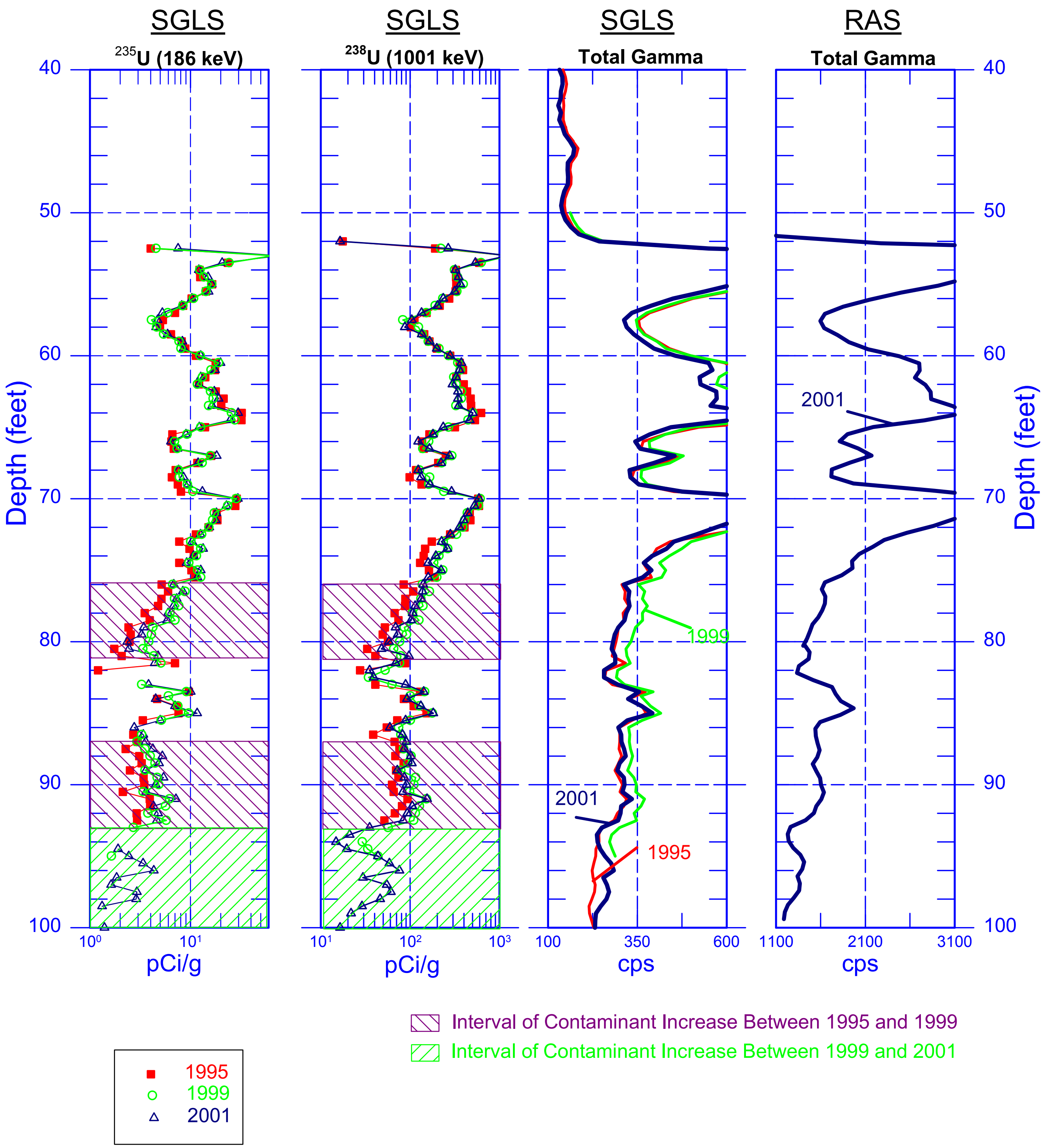


Figure 4

60-04-08
Comparison of SGLS and RAS Data

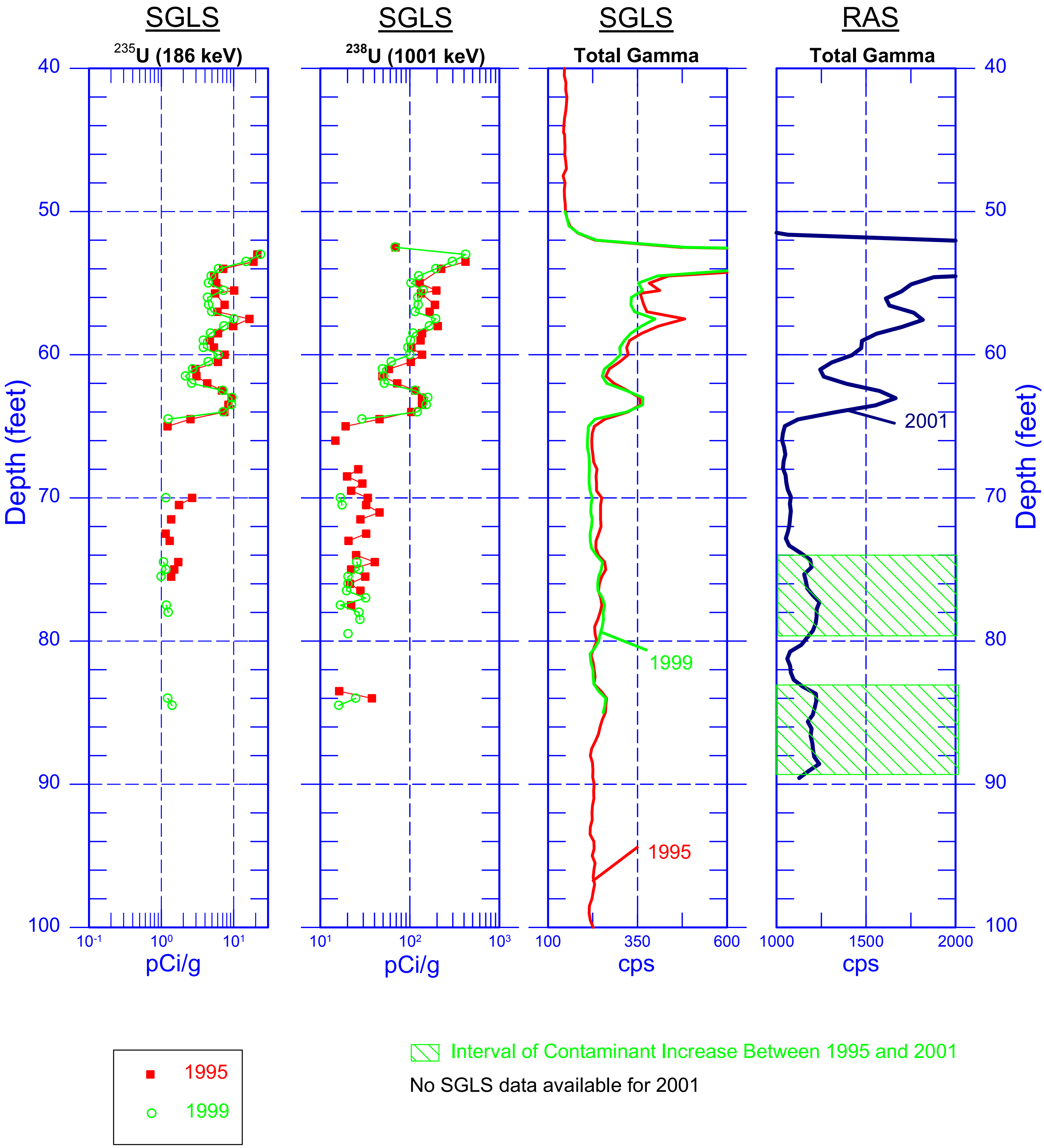


Figure 5

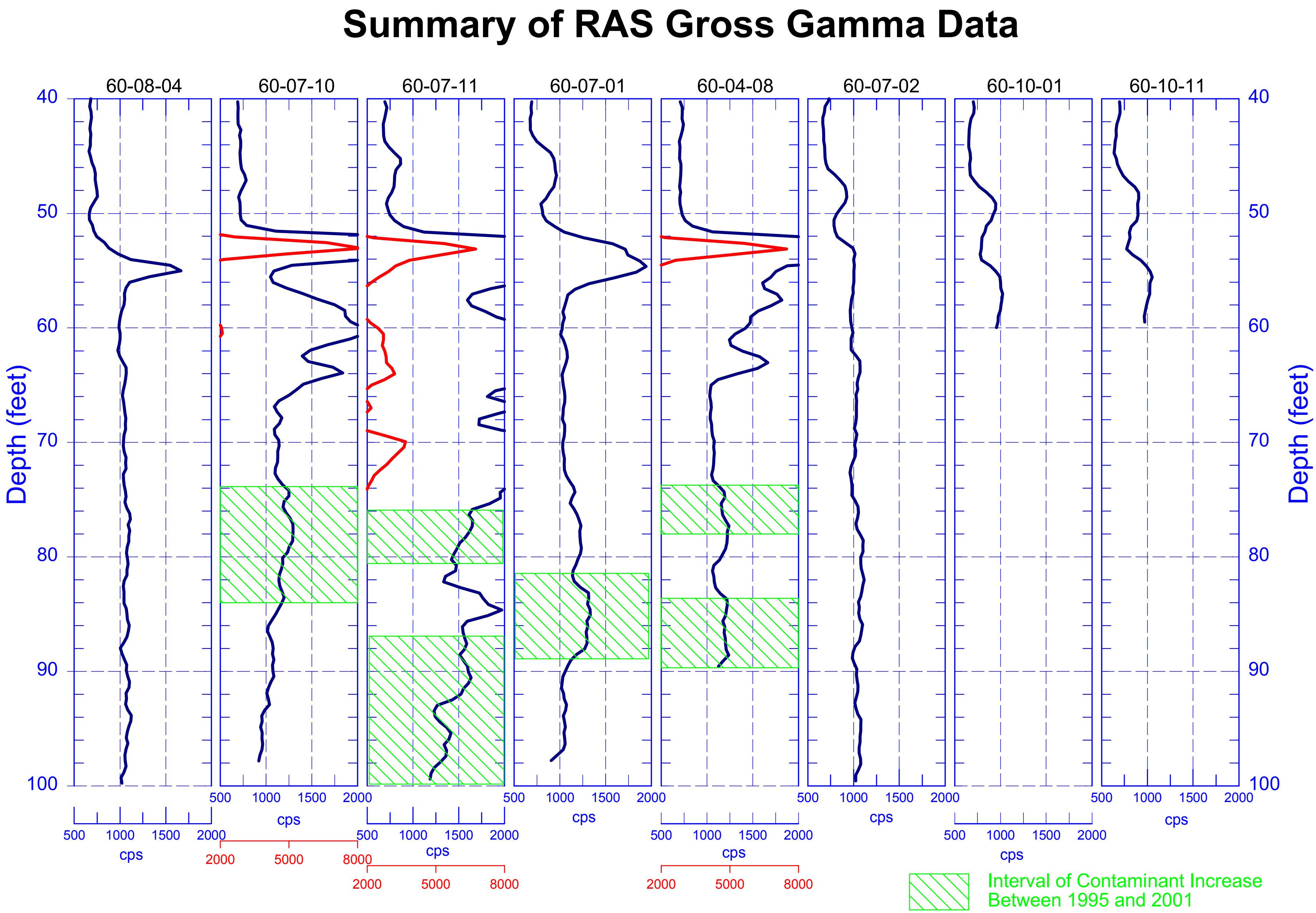

Summary of RAS Gross Gamma Data
60-08-04
60-07-10
60-07-11
60-07-01
60-04-08
60-07-02
60-10-01
60-10-11
Depth (feet)
40
50
60
70
80
90
100
500
1000
1500
2000
cps
2000
5000
8000
Interval of Contaminant Increase Between 1995 and 2001

Figure 6

Appendix E
Letter Report of Anomaly in Borehole 52-03-06

MACTEC ENVIRONMENTAL RESTORATION SERVICES, LLC

CONTRACT NO.: DE-AC13-96GJ87335
TASK ORDER NO.: MAC02-09
CONTROL NO.: 3100-T02-0617

May 14, 2002

Department of Energy
Office of River Protection
P.O. Box 550, MSIN H6-60
Richland, WA 99352
ATTN: Robert Yasek

Subject: Contract No. DE-AC13-96GJ87335—Letter Report of Anomaly in Borehole 52-03-06

Dear Mr. Yasek:

As part of the Hanford Tank Farms Vadose Zone Monitoring Project and as discussed in the Program Review meeting held yesterday, please find enclosed a copy of the subject report. As you know, MACTEC-ERS has recently identified an anomaly in monitoring data acquired from borehole 52-03-06, which appears to indicate an influx of new contamination as well as continuing migration of existing contamination. This file has already been distributed to you in electronic format.

Should you have questions or comments, please contact Rick McCain at 376-6435 or me at 376-6401.

Respectfully submitted,

James F. Bertsch,
Project Manager

JFB:jmm
Enclosure

cc w/enclosure: D. Barnes, CHG
J. Berwick, DOE-GJO
A. Knepp, CHG
J. Silko, DOE-RL
Hanford File (HGLP 1.1.5)

cc w/o: M. Butherus
P. Henwood
R. McCain
A. Pearson
W. Steele
Contract File (J. Dearborn)
JFB LB

C\...\MACTEC-ERS Letterbook FY2002\040

1100 JADWIN AVENUE, SUITE 300
RICHLAND, WASHINGTON 99352

Discussion of Anomaly in Borehole 52-03-06

RG McCain, MACTEC-ERS

May 13, 2002

Borehole 52-03-06 (299-W10-96) is located in the 241-TY tank farm, approximately half way between tanks TY-105 to the south and TY-103 to the north. The borehole was drilled in 1971 to a total depth of 100 ft. The casing is 6-inch diameter (nominal) schedule-40 steel pipe (0.280 in. wall thickness).

Both tanks have been declared leakers: TY-105 in 1960, with an estimated volume of 35,000 gallons and TY-103 in 1973, with an estimated volume of 3,000 gallons. (Hanlon, Feb 28, 2002). Both tanks were interim stabilized in 1983. Inventory values for the tanks as reported in Hanlon (Feb 28, 2002) are:

Tank	Total Waste	Supernatant Liquid	Drainable Interstitial Liquid	Drainable Liquid Remaining	Pumpable Liquid Remaining	Sludge	Saltcake
TY-103	155	0	23	23	19	103	52
TY-105	231	0	12	12	10	231	0

All volumes are in Kgal

Borehole 52-03-06 was logged with the SGLS on April 30, 1996. ^{137}Cs and ^{60}Co were detected. ^{137}Cs was measured continuously from ground surface to 5 ft depth, and intermittently from 8.5 to 14.5 ft and 56 to 61 ft. The maximum concentration was about 1.5 pCi/g at ground surface. At 56 ft, a concentration of 1.12 pCi/g was measured. ^{60}Co was detected continuously from 54 to 100 ft (total log depth), with a maximum concentration of 36.8 pCi/g at 99.5 ft. Results of shape factor analysis of the ^{60}Co peaks indicate that the contamination probably migrated through the formation rather than along the casing.

Evaluation of historical gross gamma data show an increase in gamma activity over time in the deeper portions of the vadose zone. Evaluation of historical gross gamma data by Three Rivers Scientific identified contamination from 44 to 98 ft as "unstable." "The grade thickness product for this interval showed a slow continued increase from 1975 to 1978. From 1978 to 1985 the rate of increase is slower, and from 1985 to 1994 the decrease in grade thickness product is faster than can be explained from decay of ^{60}Co." (R.R. Randall, HNF-3831, Oct, 1999)

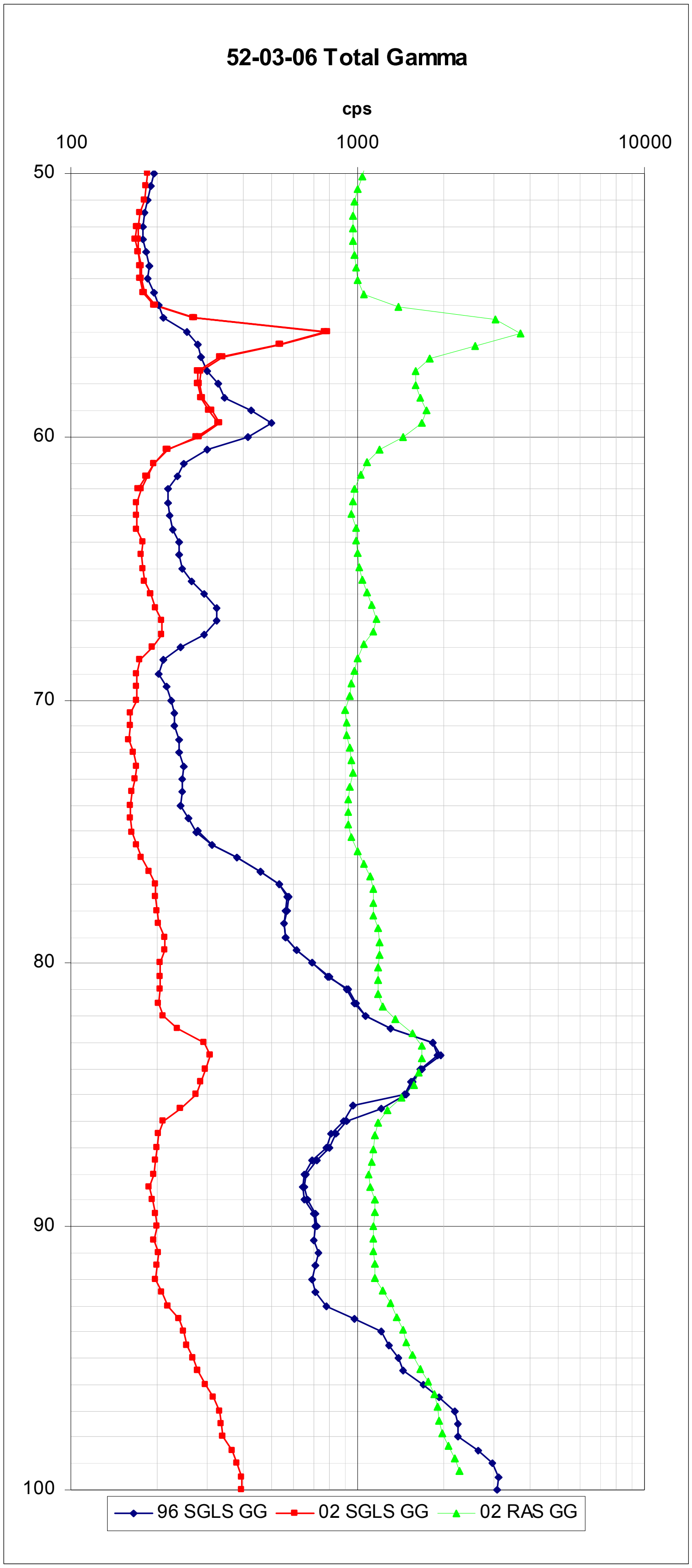
Intersection of a known contaminant plume, location between two tanks previously declared to be leaking, and the presence of drainable liquid in both tanks led to assignment of a relatively high monitoring priority for borehole 52-03-06. On May 2, 2002, the interval from 40 to 100 ft in borehole 52-03-06 was logged with the RAS (large detector). Initial review of the data detected a prominent peak at 55 to 57 ft that was not consistent with the 1996 SGLS log. Review of RAS spectra indicated the dominant contaminant in this region to be ^{137}Cs. Preliminary comparison of the RAS data with the baseline SGLS data indicate that the discrepancy between 55 and 57 ft appears to represent an influx of ^{137}Cs. Therefore, the decision was made to re-log the borehole with the SGLS as soon as possible. Additional SGLS data can be compared with the baseline to confirm the presence of an anomaly, and to estimate the magnitude of ^{137}Cs at 55 to 57 ft depth. In accordance with our project procedures, Rob Yasek (DOE-ORP) and Dave Barnes (CHG-

Tank Farms Data Evaluation) were verbally informed of the above on Friday afternoon, May 3, 2002

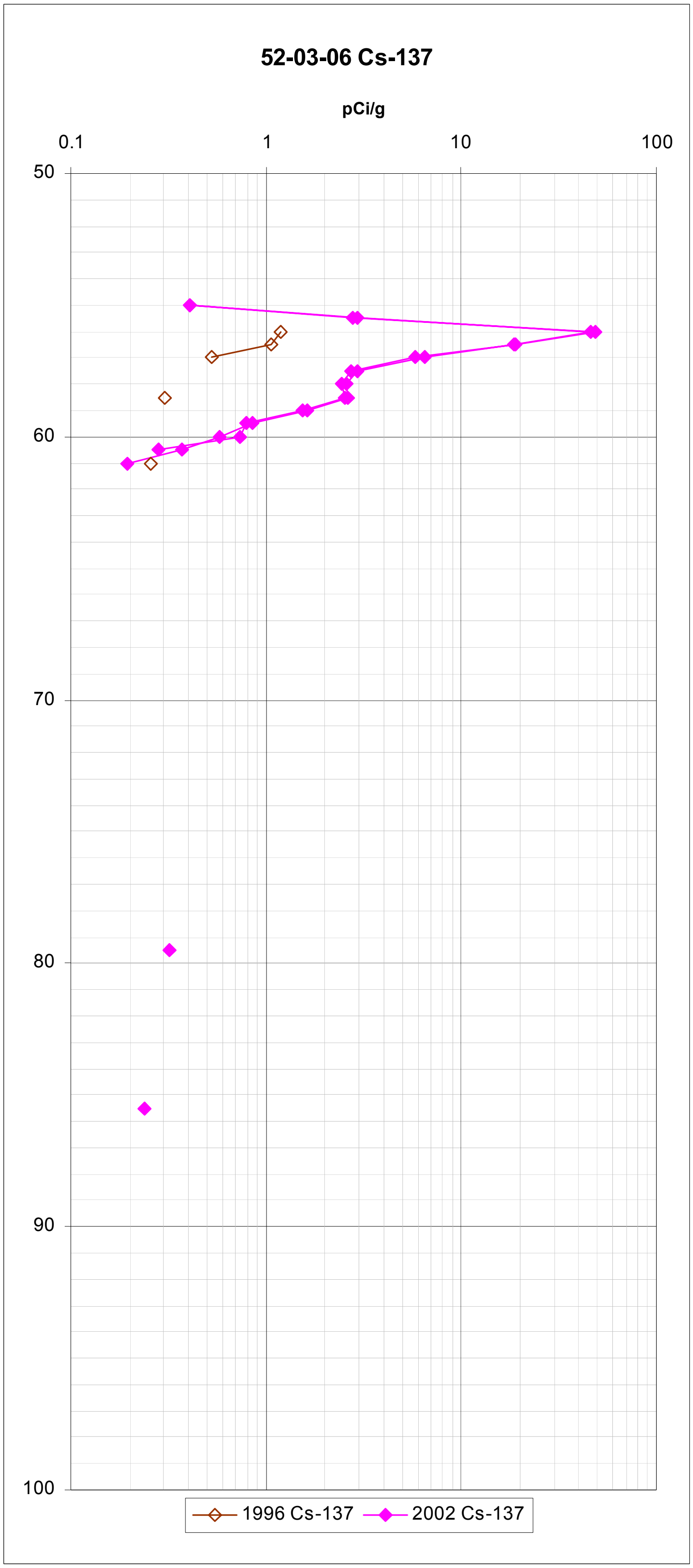
The interval from 45 to 100 ft in borehole 52-03-06 was re-logged by the SGLS on May 9, 2002. Preliminary log plots are attached. The 1996 SGLS data were reprocessed with the current casing correction function to eliminate any difference in calculated concentrations associated with variations in data processing methods over six years. Finally, ^{60}Co values from the 1996 SGLS data were decayed to 2002 (both actual and decayed values are shown on the plots). Preliminary evaluation of the SGLS data indicates a ^{137}Cs anomaly from 55 to 60.5 ft, with a maximum ^{137}Cs concentration of 48.2 pCi/g at 56 ft. This compares to a recalculated ^{137}Cs value of 1.18 pCi/g at 56 ft in the 1996 data. Also, it appears that the ^{60}Co concentration is decreasing at a rate greater than that which can be accounted for by radioactive decay. From 54 to 70 ft ^{60}Co values in the 2002 data are close to predicted values based on decay of the 1996 data. From 70 to 80 ft, 2002 values are less than half the predicted value, and below approximately 80 ft, 2002 ^{60}Co values are less than one fourth of the expected value.

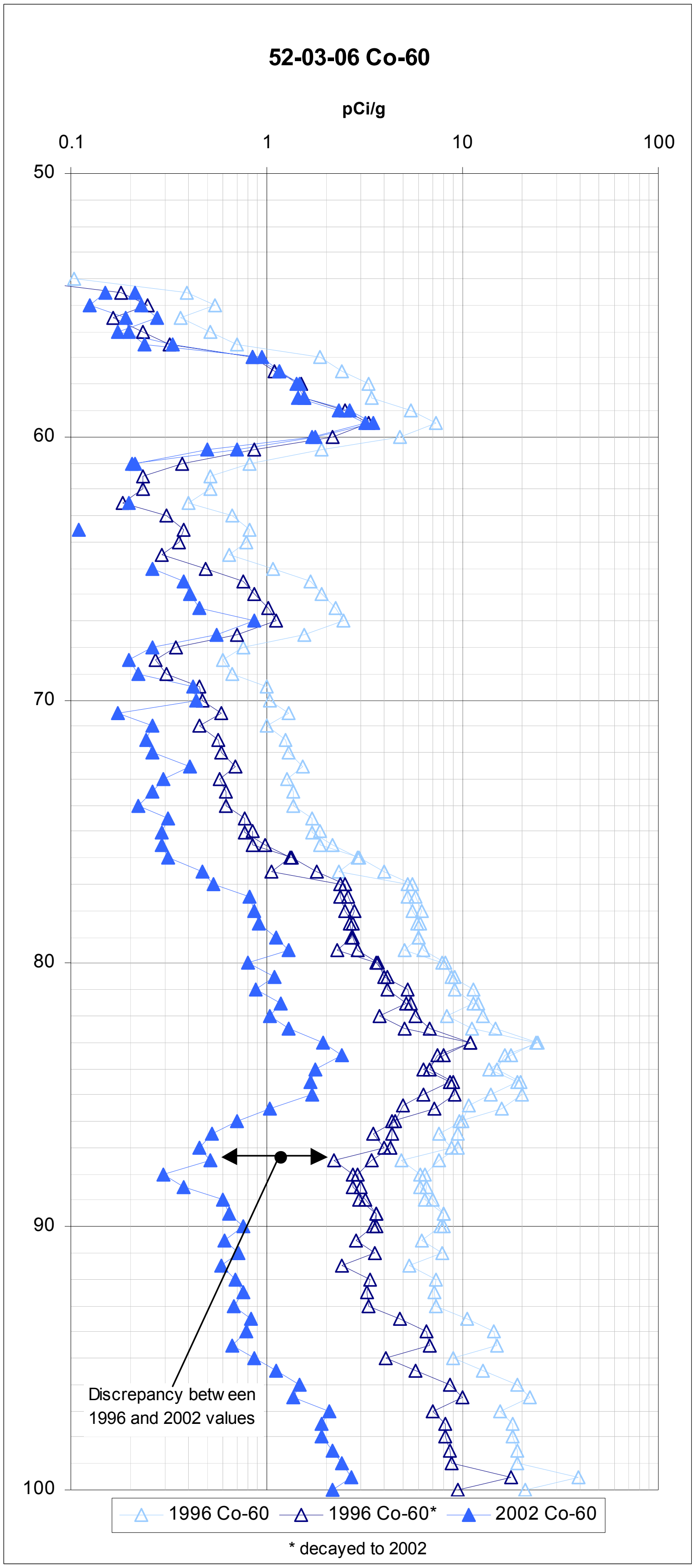
The preliminary interpretation of the log data for 52-03-06 provides the following findings:

- There is a greater than forty-fold increase in ^{137}Cs at 55 to 60.5 ft, with a maximum value at 56 ft, which suggests the appearance of a "new" contaminant plume.
- The measured levels of ^{60}Co between 54 and 65 ft appear to be decreasing at a rate commensurate with radioactive decay. From 65 ft to 100 ft (total depth) ^{60}Co concentration appears to be declining at a rate 2 to 4 times greater than can be explained by radioactive decay.
- Preliminary comparison of KUT plots for the two SGLS data sets show a very similar profile. The consistency in KUT values between 1996 and 2002 confirms the long-term performance of the SGLS logging systems and indicates that the observed variations in man-made radionuclides represent legitimate variations in contaminant levels and not instrument error. The most notable contact on the KUT plots is the base of the tank farm excavation at about 45 ft depth. Increases in ^{238}U and ^{232}Th near the bottom of the borehole may indicate a transition between the basal Hanford formation and the early Palouse/Plio-Pleistocene unit at about 93 ft. The lithology log shows a change from medium sand to silt at this depth.



52-03-06 Total Gamma
cps
100
1000
10000
50
60
70
80
90
100
96 SGLS GG
02 SGLS GG
02 RAS GG


52-03-06 Cs-137
pCi/g
0.1
1
10
100
50
60
70
80
90
100
1996 Cs-137
2002 Cs-137


52-03-06 Co-60
pCi/g
0.1
1
10
100
50
60
70
80
90
100
Discrepancy betw een
1996 and 2002 values
1996 Co-60
1996 Co-60*
2002 Co-60
* decayed to 2002

Appendix F
Moisture Logging Results in the Vicinity of Borehole 52-03-06

Moisture Anomaly in Borehole 52-03-06
P.D. Henwood
December 24, 2002

Moisture logging was performed in support of the investigation of a significant increase in ^{137}Cs levels detected by the Radionuclide Assessment System (RAS) in borehole 52-03-06 in TY Farm as documented in Occurrence Report PER2002-2444. Copies of Log Data Reports and plots for neutron moisture logs were transmitted to CHG September 11, 2002 (Steele 2002). The purpose of the logging was to assess variations in subsurface moisture content that may be related to evidence of contaminant movement.

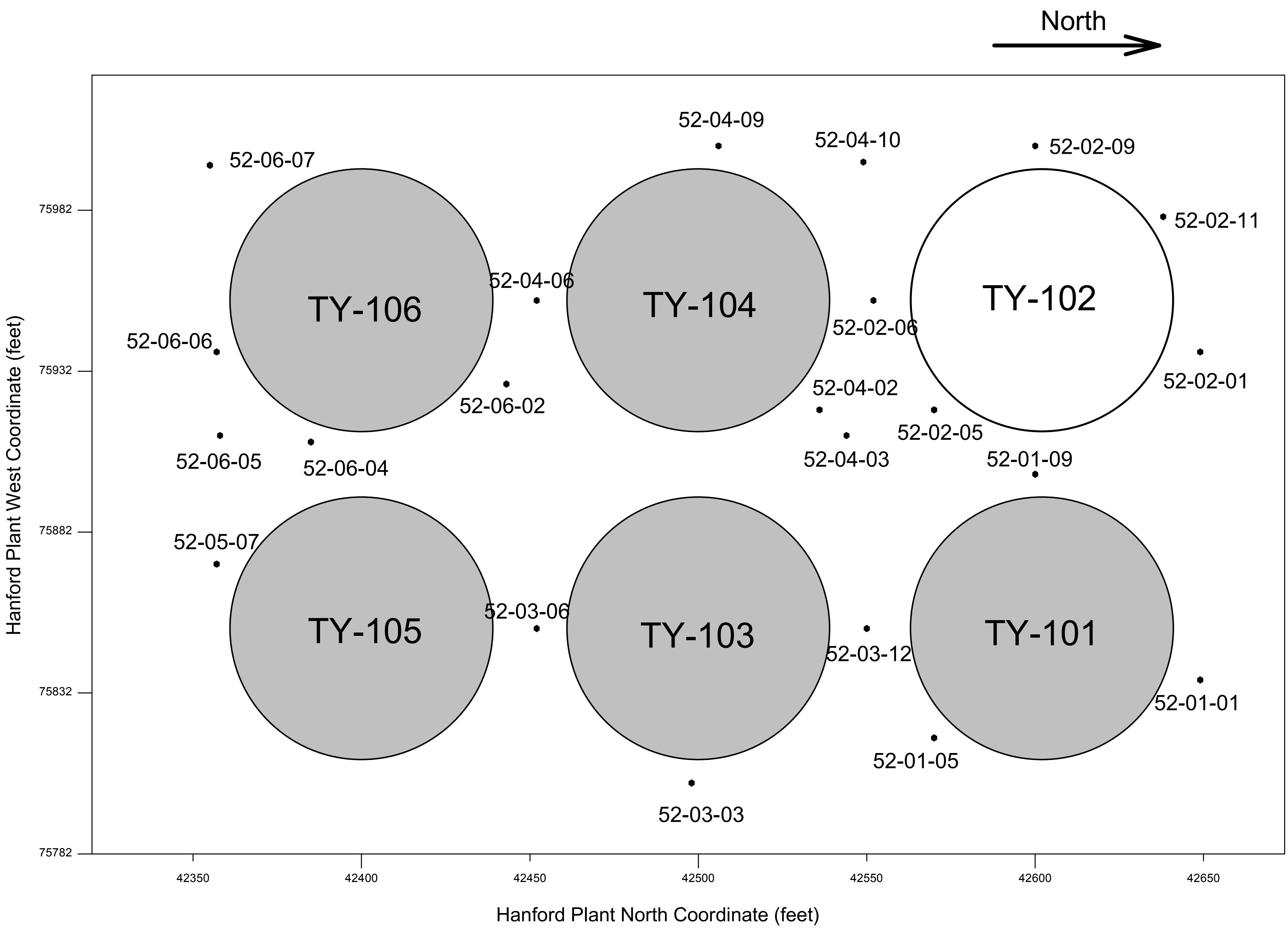
Included in this appendix are a plan view map of the TY Farm and a cross section that presents the moisture data in relation to man-made radionuclides detected in 1997 with the Spectral Gamma Logging System (SGLS). In addition to the 1997 ^{137}Cs concentrations acquired for borehole 52-03-06, the cross section includes the SGLS data collected in 2002 that shows the current ^{137}Cs and ^{60}Co concentrations. The cross sections are useful to determine the spatial relationships of man-made contaminants, lithology, and moisture in the sediments.

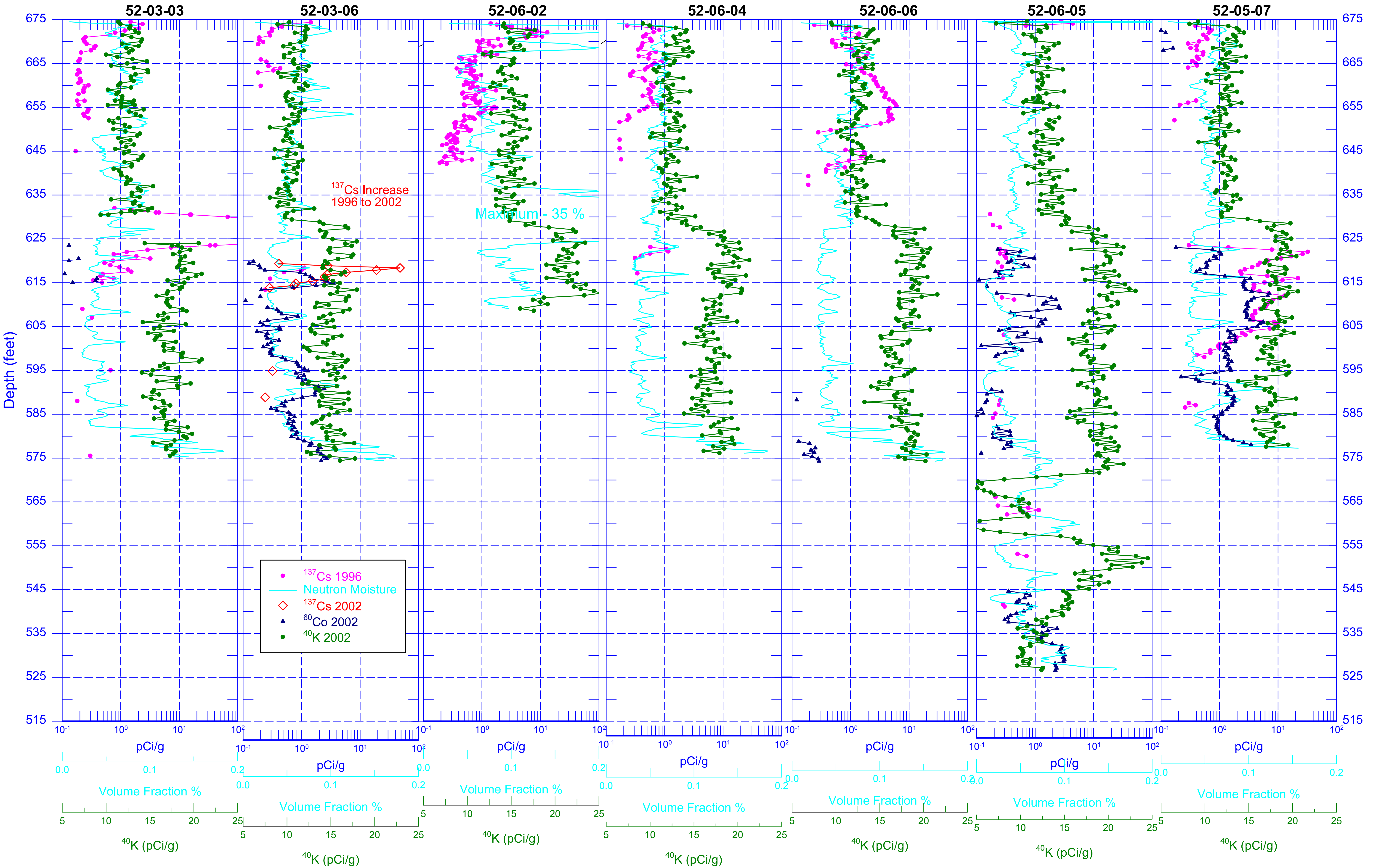
Contamination appears to often be related to higher moisture content in the vadose zone below the backfill. Borehole 52-06-02 exhibits the highest moisture content at approximately 35 percent, which approaches saturation of the sediments. It is possible this borehole is in the vicinity of a zone of high moisture that may be moving through the vadose zone. This moisture front may be remobilizing an area of ^{137}Cs contamination that exists somewhere between boreholes 52-06-02 and 52-03-06, causing an increase in ^{137}Cs concentrations near borehole 52-03-06.

Selected boreholes in TY Farm currently are being monitored on a quarterly basis with the RAS. It is recommended that moisture logging also be performed on a regular basis in the same boreholes. At a minimum, borehole 52-04-06 should be included in the next moisture monitoring event to help investigate the source of the moisture front identified in borehole 52-06-02. Ideally, moisture measurements should be acquired in all boreholes in TY Farm to establish a complete baseline against which future measurements could be compared. These measurements will help determine possible moisture sources and potential pathways for contaminant movement in the vadose zone in TY Farm. On the basis of RAS and moisture measurements, locations for additional subsurface investigations could be selected to determine the source or cause of contaminant movement identified in borehole 52-03-06 or at other locations. Presently, there are not enough boreholes in the tank farm to adequately assess subsurface contamination conditions.

<u>Reference</u>:

Steele, W.D., 2002. Letter to Robert Yasek (DOE-ORP), Subject: "Neutron Moisture Logs for Vadose Zone Boreholes in 241-TY Tank Farm," S.M. Stoller, Corp., Richland, Washington, September 11, 2002.


North
TY-106
TY-104
TY-102
TY-105
TY-103
TY-101
52-06-07
52-04-09
52-04-10
52-02-09
52-02-11
52-04-06
52-02-06
52-06-06
52-02-01
52-06-02
52-04-02
52-02-05
52-06-05
52-06-04
52-04-03
52-01-09
52-05-07
52-03-06
52-03-12
52-01-01
52-01-05
52-03-03
75982
75932
75882
75832
75782
42350
42400
42450
42500
42550
42600
42650
Hanford Plant North Coordinate (feet)
Hanford Plant West Coordinate (feet)


52-03-03
52-03-06
52-06-02
52-06-04
52-06-06
52-06-05
52-05-07
Depth (feet)
137Cs Increase 1996 to 2002
Maximum - 35 %
137Cs 1996
Neutron Moisture
137Cs 2002
60Co 2002
40K 2002
pCi/g
Volume Fraction %
40K (pCi/g)

Appendix G
Lessons Learned for the Radionuclide Assessment System

United States Government — Department of Energy

memorandum

Grand Junction Office

DATE: DEC 20 2001

SUBJECT: Transmittal of Lessons Learned for the Radionuclide Assessment System

TO: Rob Yasek, ORP/DOE-RL

Attached for your information is a lessons-learned paper regarding the Radionuclide Assessment System. Two of the significant findings are recommendations for an updated and ergonomically correct logging vehicle and the ability to detect contamination concentrations of 1,000,000,000 pCi/gm. Cesium 137 equivalent. We may want to begin discussions for funding of these items.

If you have any questions, please call me at (970) 248-6020.

Joel Berwick

Joel Berwick
Project Manager

Attachment

cc w/attachment:
J. Morse, DOE-RL
J. Silko, DOE-RL
Project File HGLP 1.1.2.2 (R. Paxton)

cc w/o attachment:
J. Bertsch, MACTEC-ERS
R. McCain, MACTEC-ERS

jdb\ras.doc

Lessons Learned in Development and Implementation of the Radionuclide Assessment System

Executive Summary

The Radionuclide Assessment System (RAS) was specifically developed to monitor gamma radiation in existing boreholes at Hanford single shell tank farms. In the course of development, a number of lessons were learned.

- A conventional pickup truck is a poor choice for a logging vehicle. Operator comfort and ergonomic issues are important considerations in the overall system design. Future logging systems should be mounted in a van or crew cab pickup.
- A heavy-duty winch is required for better stability and depth control.
- A wider measurement range is required. The original design criteria called for the ability to quantify ^{137}Cs up to 50,000 pCi/g. Concentrations in excess of 100,000,000 pCi/g were encountered during the baseline characterization effort. Future logging systems should be capable of measurement to at least 1,000,000,000 pCi/g ^{137}Cs
- The original design requirements assumed that ^{137}Cs would be the dominant gamma-emitting radionuclide present in the vadose zone. Other radionculdes, particularly ^{60}Co, europium, and processed uranium were also found in significant concentrations.
- Data analysis to determine concentration by application of spectral stripping methods was found to be impractical because of the variety of radionculides encountered, and the inability to compensate for effects of each man-made radionuclide on background count rates for other radionculides.
- Since radionuclide identification and concentration are known from the baseline characterization data, changes in gamma activity can be used to detect on-going migration. Therefore a simpler data evaluation approach based on detection of significant changes between successive logs can be applied. This uses comparison of count rates in spectral windows, rather than detailed evaluation of gamma energy spectra. (A window count is the sum of the counts in a set of contiguous multichannel analyzer (MCA) channels that span a specific energy range.)
- Monitoring measurements should be made “move-stop-acquire” mode. Holding the detector stationary during measurements will improve counting statistics, making it possible to detect more subtle changes.
- The logging system should be based on modification of an existing commercially available mineral, geotechnical or environmental logging system. DOE-GJO / MACTEC-ERS personnel should work closely with the selected vendor to adapt an existing logging system.
- A survey of available gamma ray detectors should be undertaken to identify suitable detector systems for various concentration ranges likely to be encountered at Hanford. Performance criteria include ^{137}Cs concentrations between 10^{-1} and 10^{9} pCi/g, with borehole temperatures as high as 180 to 200 °F

(82 to 93 °C) Electronic compensation systems, such as "pileup rejection," for high count rate effects would also be desirable. It is likely that a combination of detector systems will be required to achieve the required range in measurement capability.

- More attention should be given to gain stability. Magnetic and temperature effects may be significant, and should be addressed in detector design. Other effects, such as peak spreading and dead-time should also be evaluated carefully for each detector system.

Although most of the single shell tanks are considered stabilized, and short-lived radionuclides such as ^{106}Ru have decayed below detectable levels, the baseline characterization data indicate that many subsurface contaminant plumes with significant gamma activity remain. Both the observed distribution of gamma-emitting contaminants in the subsurface and independent evaluation of groundwater contamination suggest that contaminants associated with tank waste may have reached groundwater. Monitoring is an important component of future remediation activities, both to detect ongoing contaminant migration and to demonstrate stability where movement has stopped.

The lessons learned have resulted in specific recommendations for development and implementation of future monitoring systems:

- Conduct a review of available gamma detectors to identify detector system(s), which can be integrated into logging to provide a measurement range equivalent to 10^{-1} to 10^{9} pCi/g ^{137}Cs under borehole conditions of steel casing, limited diameter, high temperature, and varying magnetic fields.
- Investigate procurement of conventional "off the shelf" logging systems that can be modified for monitoring purposes and work with the vendor to adapt the system to detector(s) identified above. Issues such as vehicle weight, support requirements, depth control, operator ergonomics, data collection system, software, and operational considerations would be addressed.
- Adapt a "move-stop-acquire" logging mode instead of continuous logging to improve counting statistics and thereby facilitate identification of subtle changes in subsurface radioactivity profiles.

1. **Introduction**

Since 1995, the U.S. Department of Energy Grand Junction Office (DOE-GJO) has performed spectral gamma logging of existing boreholes in the vadose zone in the vicinity of the Hanford single-shell tanks. High resolution spectral data have been used to determine the current nature and extent of gamma-emitting contamination in the vicinity of the Hanford single shell tanks. This data set provides a baseline to which previous geophysical logs and future monitoring data can be compared to identify and assess contaminant migration or stability. With the completion of the baseline characterization project, the U.S. Department of Energy Office of River Protection

(DOE-ORP) has requested that DOE-GJO develop and implement a monitoring program in selected boreholes in the single-shell tank farms.

Prior to 1994, vadose zone monitoring was performed by Tank Farms personnel, using Geiger-Mueller (GM) or scintillation detectors. These systems recorded total gamma count rate as a function of depth. Data are available in electronic format from 1975 to 1994, and independent evaluation of these logs by others (e.g. Randall & Price, 1998) has confirmed the presence of subsurface contaminant plumes associated with tank farm operations and also provides indications of continued contaminant movement.

By the early 1990's, however, a number of serious deficiencies in the borehole surveillance program had been identified. These included (DOE-1995):

- The boreholes are not spaced closely enough around each tank to ensure detection of a leak
- The logging system did not differentiate gamma rays by energy level and was unable to identify radionculides from characteristic gamma emissions
- Logging speed and sampling intervals were inappropriate for the detectors in use and for the depth distribution of the contaminants.
- No dead-time correction.
- Inappropriate criteria for leak detection and monitoring by gamma logging.
- Inappropriate detector calibration based on point-source exposure rate standards.
- Inadequate spatial resolution as a result of large depth intervals between readings.
- The detectors were paralyzable and may not have provided accurate measurements in zones with very high gamma count rates.

In 1994, gross gamma logging was discontinued in tank farm boreholes, and plans were made to develop and implement a new monitoring system. The spectral gamma logging system (SGLS) used to acquire the baseline data set provided high-quality data, but it depended on high-purity germanium (HPGe) detectors, which are too complex and difficult to operate for routine monitoring. A simpler logging system based on thallium-activated sodium iodide (NaI(Tl)) detectors would be easier to operate and capable of faster logging speeds. This would provide more cost-effective monitoring data. The new system was originally referred to as the Leak Verification Monitoring System (LVMS), but later renamed the Radionuclide Assessment System (RAS). Development of this system began in 1995. Components, including a vehicle, winch and cable, and three NaI(Tl) detectors, were procured and a monitoring system was assembled. However, development was suspended because of funding issues. In FY2001, funding was provided to complete development of the RAS and to begin monitoring in tank farms boreholes. By July, 2001, the RAS was operational as a monitoring system.

The purpose of this document is to provide a discussion of problems and issues encountered in development and implementation of the RAS, and to describe how these problems were addressed. Individual sections will address specific components of the RAS, as well as issues associated with calibration, operation, and data evaluation. These "lessons learned" can be applied to development and implementation of future logging and monitoring systems for tank farms and other waste sites at Hanford. Many of the lessons learned can also be applied to spectral gamma logging and monitoring operations at other DOE sites.

2 Design Requirements

The SGLS used for the baseline characterization provide very high quality data, but the high-purity germanium (HPGe) detectors require liquid nitrogen cooling and relatively long count times. Moreover, data analysis and interpretation is a relatively complex process. Support requirements, data collection rate, and analytical effort argue against use of the SGLS for routine monitoring purposes. The RAS was conceived as a simple spectral gamma logging system that could be easily maneuvered inside tank farms and operated by Tank Farms personnel. Use of simpler NaI(Tl) detectors reduces support requirements and logging complexity and increases the data collection rate, albeit at the expense of energy resolution. Specific design requirements for the RAS include the following:

- Rapid deployment and ease of operation.
- Spectral gamma measurement capability
- High efficiency for good statistical precision at relatively fast logging speeds
- Detect and assay background gamma radiation associated with natural potassium (^{40}K), uranium (^{238}U) and thorium (^{232}Th) "with a precision that permits contaminant detection to the minimum concentrations specified in applicable regulations."
- Detect ^{137}Cs and ^{90}Sr
- Maximum contaminant level of 50,000 pCi/g (^{137}Cs)
- High degree of repeatability

^{90}Sr is a "pure" beta-emitting radionuclide: there is no gamma ray associated with the decay of ^{90}Sr and it is impossible to directly detect ^{90}Sr inside a steel casing, since the metal effectively shields beta particles. However, when high-energy beta particles interact with the steel casing, incoherent low-energy (<350 KeV) gamma rays known as brehmsstrahlung are generated, which can be detected inside the casing. With the SGLS, the presence of ^{90}Sr is inferred through spectral shape factor analysis, or when anomalous low-energy (< 350 KeV) gamma counts are observed with no specific peaks at energies characteristic of man-made gamma emitting radionuclides. With the RAS, the presence of ^{90}Sr is indicated by the presence of anomalous gamma counts, particularly in the spectral region below 350 KeV.

The initial design criteria were developed during the early stages of the baseline characterization project when ^{137}Cs was considered to be the primary target. Subsequent evaluation of baseline data indicated that man-made radionuclides other than ^{137}Cs are also of concern.. These include ^{60}Co, uranium (^{235}U and ^{238}U), europium (^{152}Eu and ^{154}Eu), ^{125}Sb, and ^{126}Sn. Since the baseline data set provides the identity and concentration of each radionculide within a borehole interval, it is more important that the RAS be able to detect *changes* in gamma activity between successive runs, rather than identify and quantify specific radionuclides. Although gamma spectra are collected for evaluation if necessary, routine analysis is based on comparison of count rates between successive runs.

Since counts are compared directly, additional uncertainties associated with the concentration calculations, such as casing correction or calibration error, are eliminated, making it easier to distinguish subtle changes.

Finally, results from the high rate logging system (HRLS) indicate that ^{137}Cs concentrations in excess of 100,000,000 pCi/g may be present.

3 System Components

The following is a brief description of the RAS and its individual components. More thorough descriptions are found in the *RAS Operational Test Plan Results* (DOE 2001), in the *RAS Logging Procedures* (DOE 2001), and in the *RAS Preventative Maintenance Plan* (DOE 2001).

The RAS monitoring system is mounted in a 1996 Chevrolet diesel pick-up. A DC to AC power inverter supplies 120 volt AC power for the logging and data collection system. A Mount Sopris winch moves the logging sonde in a borehole. The winch utilizes 500 ft of 0.25-in diameter, 7-conductor logging cable. A winch controller mounted in the cab of the pick-up allows the operator to control both the speed and spooling direction of the winch. The logging sonde consists of a telemetry section and a detector section. The telemetry section utilizes an Ortec Micro NOMAD MCA to collect and transmit spectra. Each detector section contains a NaI(Tl) crystal coupled to a photo-multiplier (PM) tube which is powered by an Ortec PM tube base and power supply. Three interchangeable detectors were developed to provide a wide measurement range. The primary difference between the detectors is the size (efficiency) of the sodium iodide crystal. A laptop computer is used to record the spectra, extract the window counts from each spectrum and record the depth at which each spectrum is acquired.

Nearly all RAS components were procured and assembled in 1996. When funding resumed in FY2001, there was little opportunity to make major changes in system components to take advantage of information and experience gained in the baseline characterization program. There are a number of alternative system components that could have been selected to make logging operations in the Hanford tank farms more efficient and effective. These are discussed in the following sections.

3.1 Vehicle

A 1996 Chevrolet diesel pickup was procured through GSA in Grand Junction, Colorado for use as the RAS. At the time, a van had been requested, but the pickup was the only vehicle available. The diesel engine is better suited to logging operations than a gasoline engine, since the truck is required to run at idle speed for long periods while boreholes are logged. The diesel provides more power at idle speed to support the alternator and inverter, and is less likely to overheat than a gasoline engine. However, the use of a pickup for the logging system has resulted in several problems, which will be discussed in detail below.

The logging system is operated from the passenger seat in the pickup. Since the operator must be able to observe the borehole and logging system during monitoring operations, it was necessary to reverse the passenger seat. Originally, the passenger seat was mounted on a swivel and turned to face the rear of the truck. The logging computer was located on a box that rested between the driver's seat and the passenger seat. This configuration was extremely awkward and uncomfortable because the operator had to turn sideways in the seat to operate the computer. This arrangement was changed so that the computer was mounted on a tray at the back wall of the cab. This modification allows the operator to work with the computer while facing the logging operation.

There is very little legroom with the seat facing backward. Moving the seat back (forward) as far as possible resulted in a crack in the windshield where the seat back contacted the windshield. The backrest was removed so that the seat could be moved farther back, but this resulted in less headroom for the operator because of the slope of the windshield. It has been suggested that a hole be cut into the back wall of the cab so that the operator's legs can extend into the pickup bed. While this may alleviate the cramped legroom, it will compromise the integrity of the vehicle and may result in leakage during bad weather. Operator comfort is an important consideration, because several hours are required to log most borehole intervals. Any future logging system should be installed in a van, or at least in a pickup truck with a crew or extended cab. Another possibility would be to install an enclosed operator's station in the rear of the vehicle.

Glare from ambient sunshine made it difficult to see the original laptop computer screen. This was addressed in two ways. First, a new laptop computer that used an active matrix screen was purchased. Second, the windows of the pickup were tinted. Glare can be a major problem because the logging system and data collection are controlled from the computer. It is not always possible for the operator to orient the vehicle to minimize glare. An enclosed operator station in the back of a van or in the rear of a pickup would be a more effective solution for glare.

There is a significant amount of wasted space in the bed of the pickup. A canopy is necessary to protect the logging equipment from the weather, but this restricts access to most of the space between the logging equipment at the rear of the pickup and the cab. Two pieces of equipment mounted in this space are the power inverter and the field verifier. There is very little need to access the power inverter unless repairs are required, but the field verifier needs to be accessed by the health physics technicians on a regular basis for source integrity tests and dose rate measurements. The only way to reach the verifier with the present equipment configuration is to climb over the winch.

Overall, a conventional pickup with a canopy is a poor choice for a logging vehicle. Future logging systems should be mounted in a van or a crew cab pickup. If a conventional pickup is to be used, the pickup bed should be removed and a custom body installed on the truck chassis. This would allow room for an enclosed operator station with adequate headroom and legroom, as well as better arrangement of the logging system and support components.

3.2 Logging System

The logging system consists of the winch, logging cable and winch controller used to move the sonde up and down the borehole and to transmit data signals from the sonde to the data collection system. A mast assembly positions the logging sonde over the borehole.

The original logging system had to be modified because of several deficiencies, which are discussed below.

Winch

A Mount Sopris MX series winch was originally installed in the RAS. This was a light-weight winch that used a ⅛ inch diameter single conductor logging cable. This winch had difficulties holding the sonde at a constant depth. After several attempts to correct this problem, it was determined that the weights of the sondes were near the maximum weight rating for this winch. This winch was replaced with a heavier Mount Sopris MN series winch and new winch controller.

Cable

The single-conductor logging cable complicated the computer telemetry interface because the data signal had to be carried (duplexed) on the same conductor as the down-hole power. The small diameter logging cable was also very easily kinked. The new winch is equipped with ¼ in diameter seven-conductor logging cable. The new logging cable allows the data signal and power to be run on separate conductors. This greatly simplifies the telemetry and makes the data collection system more robust. The larger diameter cable is also more resistant to kinking.

Winch Controller

The original Mount Sopris MX Series winch was controlled from two remote controllers connected to the main control console mounted on the side of the winch. One of these controllers was permanently mounted on the rear wall of the truck cab, and the other was a pendant (wired remote) that could be operated at a distance of up to 10 ft from the rear of the truck. These two controllers were built in Grand Junction and were not part of the original equipment purchased from Mount Sopris. To compensate for the weight of the sonde, a slight upward speed had to be applied to the winch motor to hold the sonde stationary in the borehole. The controllers also suffered from electrical shorts and were not compatible with the new winch.

The new Mount Sopris MN Series winch included a new controller, which is more dependable than that on the previous winch. The original RAS logging system did not include a sensor that could shut off the winch when cable tension fell outside maximum or minimum values. This is an important feature that prevents damage to the system should the sonde become stuck in the borehole or in the top sheave of the mast. The new MN series winch is equipped with a tension sensor and monitor, which allows minimum and maximum tension limits to be set. The winch is automatically shut off when these limits are exceeded.

The only drawback to the new winch controller is size. It was designed to mount in a standard instrument rack and the mounting had to be revised to fit inside the RAS vehicle cab. The controller was installed vertically inside a box that was mounted between the two seats in the cab of the truck.

Mast vs Boom

The RAS utilizes a mast and base plate assembly instead of a boom to position the logging sonde over the borehole. The original RAS used just one base plate, the 6 in diameter. This was exactly 6 inches OD and would not fit in most 6 in ID boreholes, so a new base plate with 5 ¾ in OD was made. A 3 ¾ in OD base plate was also made for use in the 4 in ID boreholes. Future logging systems should be capable of using either a mast or a boom, depending on borehole access.

Logging Mode

For monitoring purposes, logging speed and depth control are important issues. Since measurements are made by counting for a time interval while the sonde is moving in the borehole, the character of the log and the vertical range over which values are averaged depends on the interrelation between logging speed and counting time. In general, longer counting times provide better statistics, but require slow logging speed to achieve the same depth resolution. Data repeatability can be improved by operating the monitoring system in "move-stop-acquire" mode, where the sonde is held stationary for each measurement and then moved to the next depth increment.

Logging System Recommendations

In its present configuration, the logging system is adequate for monitoring purposes. Future monitoring systems should use heavy-duty winches. Depth control requirements for a monitoring system are more stringent than those for conventional logging systems. Tension limit switches are also important to prevent damage to the sonde, cable or cable head if the sonde becomes stuck in the hole or hits the sheave wheel.

3.4 Logging Sonde

The RAS sonde consists of two sections. The upper section contains a multichannel analyzer and the telemetry components. Any one of three detector modules can be connected to this section. A number of problems and issues were encountered with the logging sonde. These included the connection between the telemetry section and the detector modules, the measurement range of the detectors, gain shift, MCA/telemetry, detector housing diameters, and the borehole environment.

Module Connections

The connection between the telemetry section and the detector modules uses a pin to slip ring system. As the detector module is threaded into the telemetry section, pins on the detector module contact slip rings on the telemetry module. The slip rings are recessed inside the telemetry module while the pins are exposed at the end of the male thread connection on the detector module. This creates a potential for the pins to be broken or bent. A better design would place the pins inside the female thread on the telemetry module and the slip rings on the male thread detector sections.

Detector Range

Original design criteria required the RAS to be capable of detecting ^{137}Cs from background levels up to concentrations of about 50,000 pCi/g. This range of activity proved to be too wide for a single detector. Three detectors with overlapping ranges were purchased:

RAS NaI(Tl) Detectors

Detector	Dimensions (diameter by length, in inches)	Approximate Measurement Range (pCi/g Cs-137)	
		Minimum	Maximum
Large	3 by 12	Background	10^3 pCi/g
Medium	1.5 by 2	10 pCi/g	10^4 pCi/g
Small	1 by 1	100 pCi/g	10^5 pCi/g

Although the small detector is capable of measurements at about twice the maximum level of 50,000 pCi/g specified in the original design requirements, actual concentrations greater than 100,000,000 pCi/g have been encountered in tank farms boreholes. Therefore, additional detectors and/or shielding will be required to provide the full measurement range.

Gain Shift

Gain refers to the amplifier setting which controls how each pulse is correlated to a MCA channel number. In the detector, each gamma photon produces an electrical pulse whose height (voltage) is proportional to the energy of the gamma ray. In logging practice, gain is adjusted so that counts associated with a particular pulse height are tallied in a specified MCA channel. Over time, the gain may change slightly, so that those counts may be assigned to a different channel. Gain shift may also occur as the result of external influences, such as temperature or magnetic fields. Minor shifts in gain result in the appearance of peak spreading when pulses are shifted to adjacent channels, while major gain shifts may distort peaks to such an extent that the peaks are no longer correctly recognized. Stable gain is especially important where gamma peaks are used to identify radionuclides or where counts in spectral windows are to be compared.

Temperature effects on radiation detectors are difficult to avoid in logging practice. When logging in winter or summer, temperature variations on the order of 50 degrees Fahrenheit are possible, simply from differences in ambient air temperature and the subsurface temperature related to the normal geothermal gradient. In tank farms, thermal anomalies may be associated with intervals of intense contamination.

Magnetic fields can affect electron currents in photomultiplier tubes, which will be expressed as a gain shift. The carbon steel casing used in tank farms boreholes tends to have detectable magnetic anomalies, particularly at welded joints. When the detectors were originally fabricated, this phenomenon was overlooked and inadequate magnetic shielding was used in the detectors. If future logging systems use scintillation detectors, the photomultiplier tubes should be adequately shielded against magnetic fields.

Some detector systems use gain stabilization to help control drift. This requires that the spectra always have a recognizable peak present, which the stabilization software can use to make continuous gain adjustments. This can be accomplished by inclusion of a small radioactive source or flashing light near the detector. Obviously, the counts associated with this source add background counts to the spectrum, which must be accounted for during analysis. The current RAS system does not have gain stabilization capability. Consideration should be given to using gain stabilization in future logging systems.

MCA/Telemetry

The RAS logging system uses an Ortec MicroNOMAD MCA, which has been repackaged into the telemetry module. This MCA has a tendency to lock up during logging, requiring a system reset. Lock-up tends to occur at high count rates, and appears to be a characteristic of the system. In future logging systems, a more robust counting system should be used to avoid lock ups. Also, the concept of a downhole MCA should be reconsidered. Moving the MCA uphole would simplfy the downhole electronics, possibly eliminating the need for a separate telemetry section.

Detector Diameter

The large detector housing has an outside diameter of 4 inches, while the medium and small detector housing have an outer diameter of 3 inches. Although the RAS is designed to log boreholes with diameters as small as 4 inches, it is difficult to measure low levels in 4-inch boreholes, since the medium detector must be used.

Borehole Environment

Elevated temperatures are known to exist in some boreholes as a result of high levels of radioactive decay activity. Temperature logging in SX and A tank farms has measured borehole temperatures in excess of 160 ^{o}F. Discussions with the manufacturer of the detectors (Alpha Spectra) revealed that the detectors fabricated for the RAS are only rated to 95 ^{o}F. The RAS PM tubes are only rated to 140 ^{o}F, and the cathode material inside the tubes begins to degrade at 194 ^{o}F.

Detector Recommendations

From the above discussion on detectors, it is apparent that at least one, and probably two additional detectors will be required to increase the measurement range to concentrations as high as 10^8 pCi/g. Since the high temperatures occur in zones of high radioactivity, these detectors should be designed to function at much higher temperatures. Tentatively, 200 °F is suggested as the minimum operating temperature for high rate detectors.

The baseline characterization data provides a definition of the required measurement range for future monitoring systems, and extremes of borehole conditions in the vadose zone are known. Given such a wide range of borehole conditions and gamma flux, it is doubtful that any single detector type is ideal over the entire range. A thorough evaluation of existing gamma ray detectors should be performed to provide a basis for detector selection. Detector characteristics that are advantageous in low levels of radioactivity such as efficiency and stopping power, can become a liability in high levels of radioactivity. Factors to be considered include measurement range, size, support requirements, operating requirements, and environmental restrictions. This evaluation would be carried out by a review of publications and vendor literature, supplemented by limited testing.

3.5 Data Collection System

The data collection system includes the downhole MCA/telemetry unit, the winch controller, the depth encoder, and the laptop computer. Count data are collected in the MCA and the energy spectra are transmitted up the cable via the telemetry link. A serial (RS-232) interface transfers data from the uphole telemetry unit located in the detector power supply to the laptop computer. Depth information is transmitted to the computer from the depth encoder via an RS-232 interface. During logging, spectra are transmitted from the MCA and combined with depth information from the depth encoder. The software records counts in each of eight spectral windows, as well as total counts as a function of depth. At the end of the log run, the count data, as well as spectra files, header data and verification spectra are transferred to a 250-MB ZIP disk via a universal serial bus (USB). The ZIP disk allows monitoring data to be transferred to hard disk on the MACTEC network on a daily basis.

The existing data collection was originally set up in 1996, and modified to include the ZIP disk in 2001. In future systems, consideration should be given to replacing the serial interfaces with USB, or by using a card to collect data directly. The card could be mounted in a laptop docking station, or a rack-mounted computer could be provided if sufficient space is available.

Data Collection System Recommendations

If a conventional "off the shelf" logging system is procured as recommended, it will have a data collection and storage system developed by the vendor. Modification of this system to meet monitoring requirements is likely to be the most cost-effective option.

3.6 Operating Software

The software utilized to operate the data collection system (LVMON) was developed by MACTEC-ERS. The software stores the gamma spectra and records total counts and counts for each of eight spectral windows as a function of depth. Between 1996, and 2001, there were significant advances in computer technology. An upgrade of the laptop computer and conversion of the operating system to Windows 98 required that the original software be re-written to function in a 32-bit computing environment. As discussed above, the system experiences problems with MCA lockup at high count rates and a slow depth refresh rate. Both of these problems appear to be hardware issues. Otherwise, the software functions correctly. The primary output of the logging system is a text file containing each of the window counts, total counts, live time, and dead time as a function of depth. This file can be directly imported to Microsoft EXCEL® for data analysis.

Operating Software Recommendations

If a conventional "off the shelf" logging system is procured as recommended, it will have operating software developed by the vendor. Modification of this software to meet monitoring requirements is likely to be the most cost-effective option.

4. Calibration

Since the baseline characterization data provide radionuclide identification and initial concentration, the primary function of the RAS is to detect changes in gamma activity over time. Because calculation of concentrations is not the primary objective, it is not necessary to calibrate the RAS in the usual sense. That is, no correlation between instrument response and concentration has been derived. Initially, it was thought that the system could be calibrated to determine ^{137}Cs concentration by subtracting or "stripping" the contribution of naturally occurring potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th) from a ^{137}Cs window that would be defined to capture counts due to the 661.6-keV 137Cs gamma ray. Coefficients for the stripping calculations could be determined from measurements in the GJO and Hanford calibration models. However, the presence of other man-made radionculides such as cobalt-60 (^{60}Co) and europium 152 and –154 ($^{152/154}Eu$) cannot be accounted for in the stripping process, unless calibration models are constructed to isolate the effects of each radionuclide on background levels for the others. Therefore, the decision was made to compare counts in pre-defined spectral windows to assess changes in activity. Measurements have been made at GJO and in the Hanford calibration models to assess the performance of the RAS detectors in known radiation environments and to determine measurement precision.

4.1 Initial Calibration

Calibration measurements were made with the RAS in the GJO calibration models in FY1996 and at the Hanford calibration models in FY2001. Data from these measurements were used to determine system characteristics. For example, the system dead time effect was investigated and found to be negligible, and the overall measurement precision was determined to be suitable for monitoring purposes. Results of the initial calibration are discussed in detail in *Initial Calibration of the Radionuclide Assessment System* (Koizumi, 2001).

4.2 Verification Measurements

Verification measurements are made to assess the day-to-day performance of the logging system. A portable, sealed potassium-uranium-thorium (KUTh) source was acquired for field verification measurements. This source contains potassium, uranium and thorium compounds. Activities of decay progeny in the uranium and thorium series are presumably in secular equilibrium with the parent radionuclides. This represents a relatively stable source and daily measurements made with this source can be used to assess detector performance over time.

5. Operational Issues

Hanford Tank Farm personnel operate the RAS system, and two operators are assigned to operate the system on a daily basis. Six operators have been training on the system and have satisfied a qualification requirement of the tank farms contractor CH2M Hill Hanford Group (CHG). A meeting was held with all six operators to collect their input on operational issues of working with the RAS. The discussions below summarize their suggestions.

The main complaint was the vehicle itself and in particular the limited legroom for the operator. They suggested using a full-size (3/4 ton) diesel van. The van should be equipped with swiveling cloth captain's chairs so both operators can view the computer screen. The gross vehicle weight should be kept under 10,000 lbs to avoid dome loading issues. Other options suggested by the operators were that the van should have tinted windows, a protective plate for the fuel tank and a block heater.

The operators liked the current winch installed on the RAS but would like to have the following modifications: 1) a remote winch controller at the rear of the vehicle, 2) computer control and, 3) faster speed for retrieving the sonde from the borehole. They also like the idea of using a boom instead of the mast assembly. The mast assembly would still have to be used (in combination with the boom) for inaccessible boreholes.

The logging sonde should be made as light as possible, preferably less than 40 lbs. The operators would also like to eliminate the telemetry section all together.

Their main suggestion concerning the computer and software was to have the computer control the winch, and that the computer be equipped with a cordless or trackball mouse. Another suggestion was to change the software so all readouts were near the same location on the screen, and revise the software so that data transfer to the ZIP drive could be completed once per day.

Other suggestions that were offered during the meeting included the following: 1) install a base radio in the truck, 2) use a larger engine hour meter, 3) install a shore power hook-up, 4) utilize better designed, more ergonomically efficient equipment storage, 5) better access to the KUTh verifier, 6) extra 110 V ac outlets and, 7) external flood lights.

6. Data Analysis

The development of a data analysis methodology for the RAS is discussed in detail in Appendix A. Originally, the intent was to calculate ^{137}Cs concentrations by stripping or subtracting the contribution from naturally occurring radionculides associated with ^{40}K, and the ^{238}U and ^{232}Th decay series. This is possible when only one target radionuclide is present, but becomes impossible when a variety of man-made radionuclides may be present. Energy resolution capability of NaI(Tl) detectors is not adequate to isolate specific energy lines. Measurement is based on counts recorded in relatively broad spectral windows. The background counts in each window due to other radionuclides must be subtracted to determine the counts associated with the target radionuclide. The existing calibration models are adequate to determine the effects of naturally occurring radionuclides on background counts in any spectral window, but calibration would require an additional series of models to determine the effects of each target radionuclide on background counts in each spectral window. Since both radionuclide identity and concentrations are known from the baseline characterization data, it is not necessary to determine concentrations with the RAS. A simplified data analysis approach oriented toward detecting changes in subsurface radioactivity levels is more appropriate.

The gamma spectra recorded by the RAS is subdivided into eight contiguous windows and count rates are recorded for each window. The rationale behind the definition of each window is discussed in Appendix A.

To a first approximation, changes in contamination profiles can be identified by simply comparing plots of successive log runs. When necessary, count rates can be corrected for decay using radionuclide identification from the baseline data. Areas of possible contaminant migration can be identified by changes in count rate over a depth interval or changes in the depth over which anomalous activity occurs.

Like all radiation measurements, RAS data are subject to random fluctuations associated with the radioactive decay process. Therefore, it will be necessary to determine if observed differences in count rates are statistically significant. This follows a method described in Knoll (2000), in which limits are established at a pre-determined level of significance. One limit defines the level at which there is no statistically significant difference in count rates, and the second limit defines the level at which a statistically significant difference in count rates exists. The mathematical derivation of these limits is discussed in Appendix A.

Data Analysis Recommendations

The current graphical scheme of data analysis is relatively simple and quickly identifies changes in radioactivity levels. This allows data interpretation to be carried out quickly after logging is completed. When necessary, gamma spectra can be examined for more information, and the SGLS or HRLS can be used if more precise measurements are required.

The data analysis approach for future logging systems will be based on the most effective method for the specific detector system(s).

7. Conclusions

The RAS was successfully completed and deployed to conduct monitoring operations in boreholes surrounding the Hanford single shell tanks. Although a number of problems were encountered, the RAS has proven useful in detecting intervals of potential contaminant movement in the vadose zone. The data can be quickly plotted for visual analysis or a more detailed statistical analysis can be performed as necessary.

Even though the SSTs are being stabilized and tank contents are being transferred to double shell tanks, contaminant plumes exist in the subsurface, and a monitoring program is necessary to detect any continuing migration. Although short half-life radionuclides such as ^{106}Ru have decayed below detectable levels, and other radionuclides that constitute the greatest risk, such as ^{90}Sr or ^{99}Tc, cannot be detected directly with gamma measurements in cased holes, the baseline data and monitoring experience to date indicate that significant levels of gamma activity remain in the vadose zone. Results of the baseline characterization and independent evaluation of groundwater data indicate that contaminant plumes from SST leaks may have impacted groundwater. The mobility of these contaminant plumes is an important factor in assessing the ultimate risk to human health and the environment, and in selecting and implementing appropriate remedies. Where contaminant plumes are shown to be stable, consideration can be given to leaving the material in place to attenuate naturally through radioactive decay, with appropriate monitoring. For example, ^{137}Cs plumes with concentrations in excess of 10^8 pCi/g have been detected. Excavation, transport and disposal of soil with these contamination levels will result in a significant radiation dose to remediation workers and represents a potential for airborne contamination. ^{137}Cs has a half-life of 30.7 years and seems to be relatively immobile in the subsurface now, even though it was apparently carried great distances in the past by movements of liquids from tank leaks.

8. Recommendations

The baseline characterization, independent evaluation of historical gross gamma data, and assessment or groundwater data all indicate that significant vadose zone contamination exists. Monitoring gamma-emitting contaminants in the vadose zone through existing boreholes is an important and cost-effective component of the overall site remediation effort and should be continued. Monitoring is also important in boreholes around tanks in which retrieval operations are underway, particularly when liquids are being added as part of the retrieval process. At present, only one system is available to support monitoring operations in almost 800 boreholes. Additional systems must be procured to support a reasonable monitoring frequency, as well as to avoid major gaps in the monitoring program that might result from equipment failure. Also, the ongoing vadose zone baseline characterization project has been extended to existing boreholes in and around liquid waste disposal sites in the Hanford 200 Areas. Evidence of subsurface contamination has already been detected in a number of these boreholes, and it is likely that many will require monitoring in the future.

Although the RAS has been effective in monitoring operations for tank farms, lessons learned in its development and implementation have identified a number of shortcomings, which should be corrected in subsequent monitoring systems. Given below are specific recommendations for development and implementation of borehole logging systems for monitoring at the Hanford Site.

- **<u>Extend Measurement Capability to 1,000,000,000 pCi/g ^{137}Cs</u>**
  The existing RAS is capable of measurements up to about 100,000 pCi/g. This is about 4 orders of magnitude below the required capability. Additional detectors and shielding will be required to achieve this range.

- **<u>Perform a Review of Available Gamma Detectors</u>**
  The ability to make reliable and repeatable measurements in zone of intense gamma flux is an important requirement for the monitoring system. NaI(Tl) detectors generally work well at low to intermediate count rates, but may not be

the best choice in high rate zones. Detector characteristics that are advantageous at low levels of radioactivity may become liabilities at high activity levels. Environmental factors, such as borehole temperature and magnetic fields associated with steel casing must also be addressed. The detector review would rely on published literature and vendor information to identify and evaluate various detectors and detector configurations suitable for all or part of the anticipated measurement range. The goal would be to identify optimum detectors for specific radiation levels and borehole conditions, and to integrate those detectors within sondes compatible with the new logging system.

- **Procure a Conventional Logging System**
  Several companies, notably Century Geophysical and Mt Sopris Instruments, manufacture integrated logging systems for mineral, geotechnical and environmental applications. These systems are typically mounted in a crew cab pickup or van and provide power supply, winch, winch control, depth encoding and data collection systems that are specifically designed for logging operations. Many of the ergonomic and equipment compatibility issues encountered with the RAS development will already have been addressed. These companies can also provide detectors that can be used at Hanford. For example, conventional spectral gamma and neutron moisture detectors could be used in intervals of low contamination. Many commercially available sondes are designed to be run in combination. This allows gamma counts and neutron moisture data to be collected in a single pass. Some degree of equipment and software modification will likely be required to deal with man-made gamma emitting contaminants, which are not usually encountered outside the DOE environment. This can be best accomplished by working in cooperation with engineers who have experience in development of conventional logging systems. Specific factors to be evaluated as part of the logging system procurement would include:

  - Gross vehicle weight and maneuverability
  - Support requirements
  - Operator ergonomics, equipment access and operational considerations
  - Winch stability, depth control and logging speed
  - Electrical system
  - Data collection system and software
  - Compatibility with special-purpose detectors identified above.
  - Capability for modification to accommodate special requirements associated with monitoring man-made radionuclides

- **Hold the detector stationary for measurements**
  Baseline data indicate that contaminated intervals frequently occur as very thin zones. Radiation levels can change rapidly over very short depth increments. If the detector is moving as spectra are acquired, then radiation levels may change significantly during the count time. This may affect the counting statistics, making it more difficult to detect subtle changes. When the detector is held stationary, the radiation field is constant during the count time, and response is

more predictable. Also, it is not necessary to maintain stable sonde movement speeds to the same level of precision.

9. References

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Appendix A
RAS Data Evaluation

The original approach to analysis of the data acquired with the RAS was based on work of R.D. Wilson and D.C. Stromswald (1981) as part of the National Uranium Resource Evaluation (NURE) program. It used counts in three spectral windows referred to as the K, U, and T windows. The K window collected counts due to the 1460.8 keV peak associated with ^{40}K, the T window collected counts due to the 2614.5 keV peak associated with ^{232}Th, and the U window collected counts due to the 1764.5 and 2204.1 keV peaks associated with ^{238}U. Nuclides in the ^{238}U and ^{232}Th decay series give rise to many gamma rays with various energies, so that the counts in each window are a function of all three radionuclides. Potassium, uranium and thorium concentrations were calculated from the matrix equation:

$$\begin{bmatrix} K_{con} \\ U_{con} \\ T_{con} \end{bmatrix} = [A]^{-1} \begin{bmatrix} K_{win} \\ U_{win} \\ T_{win} \end{bmatrix} \tag{1}$$

Where K_{win}, U_{win}, and T_{win} are the respective window count rates, and K_{con}, U_{con}, and T_{con} are the concentrations. $[A]^{-1}$ is a 3 X 3 matrix called the calibration matrix, whose elements are determined from measurements in calibration models where K_{con}, U_{con}, and T_{con} are known. This approach is commonly used in conventional spectral gamma logging, where man-made gamma emitting radionuclides are not expected to be present.

This approach was originally considered because the key potassium, uranium, and thorium gamma rays have higher energies than the ^{137}Cs gamma ray (661.6 keV), and ^{137}Cs was thought to be by far the predominant constituent in subsurface contamination. Gamma rays from ^{137}Cs would not contribute significantly to the counts in the K, U, and T windows, and the count rates in those windows could therefore be used to calculate the potassium, uranium, and thorium concentrations. Using the concentrations, the potassium, uranium, and thorium count rate contributions to a cesium window centered at 661.6 keV could be calculated, and the count rate due to ^{137}Cs alone could be inferred. Presumably, the count rate due to ^{137}Cs would be proportional to the ^{137}Cs concentration.

A fundamental assumption in the NURE approach is that both the uranium and thorium decay series are in secular equilibrium, since the sources of the peaks used are daughter nuclides well down in the decay chain. The 1764.5 and 2204.1 keV gamma rays used for uranium are emitted by ^{214}Bi and ^{214}Pb, respectively, while the 2614.5 keV peak used for thorium is emitted by ^{208}Tl. Under the assumption of secular equilibrium, the activity of the parents ^{238}U and ^{232}Th can be calculated. The time required for attainment of secular equilibrium is on the order of several million years, so man-made (chemically processed) uranium does not result in elevated gamma activity at these energies. However, the presence of radon may affect uranium window counts. ^{222}Rn is a highly mobile gas. ^{214}Bi and ^{214}Pb are short-term radon daughters, so secular equilibrium with ^{222}Rn is achieved in a matter of hours. The presence of excess ^{222}Rn will thus result in anomalous counts in the U window, while the K and T windows are relatively unaffected.

By the time the development of the RAS was being completed, results of the initial baseline characterization in the twelve tank farms indicated that a number of man-made radionuclides in addition to ^{137}Cs were present in significant amounts. Table 1 lists major man-made radionuclides encountered during the Hanford Tank Farms Vadose Zone Characterization Project.

Table 1. Man-made radionuclides detected by the Hanford Tank Farms Vadose Zone Characterization Project

	half life	Primary Gamma Rays		Secondary Gamma Rays	
radionuclide	years	E, keV	Y, %	E, keV	Y, %
^{60}Co	5.2714	1332.50	99.98		
		1173.24	99.90		
^{125}Sb	2.7582	427.88	29.60	600.60	17.86
				635.95	11.31
				463.37	10.49
^{126}Sn	1.E+5	414.50	86.00	666.10	86.00
				694.80	82.56
^{137}Cs	30.07	661.66	85.10		
^{152}Eu	13.542	1408.01	20.87	121.78	28.42
				344.28	26.58
				964.13	14.34
				1112.12	13.54
				778.90	12.96
^{154}Eu	8.593	1274.44	35.19	123.07	40.79
				723.31	20.22
				1004.73	18.01
				873.19	12.27
^{235}U	7.04E+8	185.72	57.20		
^{234}Pa (man-made ^{238}U)		1001.03	0.84	811.00	0.51
				766.36	0.29

Unfortunately, the data analysis approach described above could only be used to detect and quantify ^{137}Cs in the absence of other man-made radionculides. If, for example, ^{154}Eu were present in addition to ^{137}Cs, the ^{154}Eu gamma rays would also contribute counts to the Cs window, and the amount of ^{137}Cs would be over-estimated. Worse, the ^{154}Eu would most likely go undetected because the gamma rays listed in the table above would not be counted in the potassium, uranium, or thorium windows.

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The adaptation of the NURE spectral stripping technique is ineffective for Hanford logging because multiple man-made gamma-ray sources produce backgrounds in the cesium window that cannot be calculated. Measurements from which to derive background subtraction coefficients cannot be made because there are no calibration standards that contain the necessary man-made radionuclides, both individually and in combination. Evaluation of gamma energy spectral peaks instead of window counts is not feasible because the NaI(Tl) detectors have such poor energy resolution that the spectra from contaminated zones contain numerous obscure and overlapping peaks.

These considerations led to a re-evaluation of the overall analytical approach. Specific radionuclides have been identified by the baseline characterization program, and concentrations are known. Therefore, the primary goal of the RAS is to detect *changes* in radioactivity levels. Decreases in concentrations consistent with radioactive decay are expected, but contaminant migration may be indicated by either increases or decreases in radioactivity levels that cannot be explained by decay.

A revised analytical approach was developed which is still based on spectral windows. The four spectral windows for Cs, K, U and T are retained (although the energy ranges have been modified) and four additional windows are defined to cover the entire energy range of the detector. Counts are collected for all eight windows as well as total counts. Table 2 identifies the energy range of each spectral window. Channel ranges for each detector are also listed.

Table 2. RAS Energy Windows

	Window	Energy range keV	Channel range		
			Large (L)	Medium (M)	Small (S)
1	Lithology	0 – 570	0 – 52	0 – 49	0 – 52
2	Cesium	570 – 740	53 – 68	50 – 64	53 – 67
3	Midrange	740 – 940	69 – 86	65 – 80	68 – 84
4	Protactinium	940 – 1060	87 – 97	81 – 90	85 – 95
5	Cobalt	1060 – 1390	98 – 126	91 – 118	96 – 123
6	Potassium	1390 – 1600	127 – 145	119 – 135	124 – 140
7	Uranium	1600 – 2400	146 – 214	136 – 200	141 – 206
8	Thorium	2400 – 2800	215 – 255	201 – 255	207 – 255

The potassium, uranium and thorium windows are defined to track naturally occurring radionuclides. The cesium and cobalt windows are defined to track specific man-made radionuclides. A protactinium window captures counts from protactinium-234m (^{234m}Pa), an early daughter in the ^{238}U decay series, which quickly reaches secular equilibrium with the parent ^{238}U. Because ^{234m}Pa has a relatively low gamma yield, its characteristic gamma rays are not detected from natural uranium at typical concentration levels. Hence, the presence of gamma rays associated with this radionuclide can be taken as an indication of purified uranium in which the decay series has been perturbed by chemical processing, so that the concentration of ^{238}U is high, but the concentrations of the uranium decay progenies below ^{234m}Pa are extremely low. Finally, the lithology and midrange windows fill the gap between the other windows. The sum of counts in the eight individual windows should be equal to the total counts.

To a first approximation, changes in count rates can be identified by simply comparing plots of successive log runs. When necessary, decay corrections can be made using radionuclide identification from the baseline data. Areas of possible contaminant migration can be identified by changes in count rate over a depth interval or changes in the depth over which anomalous activity occurs.

Like all radiation measurements, RAS data are subject to random fluctuations associated with the radioactive decay process. Therefore, it will be necessary to determine if observed differences in count rates are statistically significant. This follows a method described in Knoll (2000).

N_1 and N_2 designate two individual measurements taken at different times (assume appropriate decay corrections have been made to correct both count rates to a common time). Both are taken to be estimates of the mean value of a Gaussian distribution at the time of measurement. The estimate for the standard deviation is equivalent to the square root of the counts.

$$\sigma = \sqrt{N} \tag{2}$$

The count rates, R_1 and R_2, are determined by dividing the counts by the live time. The count rate also represents a Gaussian (normal) distribution, since $R = N/T$. The estimate of the standard deviation for the count rate is:

$$\sigma = \frac{\sqrt{N}}{T} = \frac{\sqrt{RT}}{T} = \sqrt{\frac{R}{T}} \tag{3}$$

The difference in count rates between the measurements should also follow a Gaussian distribution.

If there is no actual difference in the two counts, then the true mean values for R_1 and R_2 are the same and:

$$\sigma_{\Delta R} = \sqrt{\sigma_{R_1}^2 + \sigma_{R_2}^2} \tag{4}$$

We can define a critical level, L_1, so that the probability of false positives is minimal. For the purpose of this analysis, we will accept a 5% chance for a false positive result. For a one-tailed normal distribution, there is a 95% probability that a random sample of R_2 will lie below the mean + 1.645 σ when R_2 and R_1 are taken from the same distribution.

Also, $\sigma_{R1} \approx \sigma_{R2}$, so that: $$\sigma_{\Delta R} = \sqrt{\sigma_{R_2}^2 + \sigma_{R_1}^2} = \sqrt{2} \times \sigma_{R_1} \tag{5}$$

Therefore: $$L_1 = R_1 + 1.645 \times \sqrt{2} \times \sigma_{R_1} = R_1 + 2.326 \times \sigma_{R_1} \tag{6}$$

In the case where a real difference in activity exists, the true mean value for ΔR is >0, and we can define a minimum limit for R_2 for which the probability of false negatives is minimal. If $R_2 = L_1$, the false negative rate will be 50 %, because a Gaussian distribution is symmetric about its mean. To ensure that 95 % of the values in the R_2 distribution lie above L_1, we define L_2 so that:

$$L_2 = L_1 + 1.645 \times \sigma_{\Delta R} \tag{7}$$

also, $\sigma_{R2} \geq \sigma_{R1}$, so that: $\sigma_{\Delta R} = \sqrt{\sigma_{R_2}^2 + \sigma_{R_2}^2} \leq \sqrt{2} \times \sigma_{R_2}$ (8)

Therefore: $L_2 = R_1 + 2.326 \times \sigma_{R_1} + 2.326 \times \sigma_{R_2}$ (9)

L_2 defines the level above which there is a 95% probability that the count rates are different.

For radiation measurements, $\sigma_N \approx \sqrt{N}$: $\sigma_R = \sqrt{\frac{R}{T}}$ (10)

This leads to definition of two limit values based on count rates, which can be used to compare successive monitoring runs.

$$L_1 = R_1 + 2.326 \times \sqrt{\frac{R_1}{T_1}} \tag{11}$$

$$L_2 = R_1 + 2.326 \times \sqrt{\frac{R_1}{T_1}} + 2.326 \times \sqrt{\frac{R_2}{T_2}} \tag{12}$$

Data evaluation consists of comparing the second count rate to these limits:

$R_2 \leq L_1$ $\Rightarrow$ no significant difference (95%)

$L_1 < R_2 < L_2$ $\Rightarrow$ ambiguous

$R_2 \geq L_2$ $\Rightarrow$ significant difference (95%)

Values for R_1, L_1 and L_2 should be corrected for decay for the time at which R_2 is measured. These values may be calculated for specific windows or for total counts. When the second count rate lies between L_1 and L_2, it is likely that a difference in count rates exists, but at a lower confidence interval. In this case, the ambiguity can possibly be resolved by comparing with a previous count rate over a longer time interval, comparing changes in a different window, or by calculating new limits based on a lower degree of confidence.

The above equations are relatively simple and can be implemented in a Microsoft EXCEL® spreadsheet. Data from the RAS consists of window counts as a function of depth written as text files. These files can be imported to the spreadsheet and plotted or analyzed in greater detail when necessary. If needed, decay corrections can be easily calculated and applied.

Appendix H
Boreholes Projected for Monitoring During the First Quarter of FY 2003

Appendix H. Boreholes Projected for Monitoring During First Quarter of FY 2003

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
10-00-07	A-101	45	85	40		89	06/15/02		06/20/01					No apparent change
10-00-08	A-101	45	85	40		89	06/20/02		06/25/01					No apparent change
10-01-05	A-101	45	85	40		89	06/15/02		06/20/01					No apparent change
10-01-06	A-101	45	85	40		89	06/22/02		06/27/01					No apparent change
10-01-08	A-101	45	85	40		89	06/22/02		06/27/01					No apparent change
10-01-09	A-101	45	63	18		89	06/21/02		06/26/01					No apparent change
10-01-10	A-101	45	85	40		89	06/22/02		06/27/01					No apparent change
10-01-11	A-101	45	85	40		89	06/22/02		06/27/01					No apparent change
10-02-01	A-102	45	95	50		32	11/13/97							
10-02-03	A-102	45	125	80		32	10/27/97							
10-02-08	A-102	45	95	50		32	11/03/97							BE - Cs-137
10-03-07	A-103	45	125	80		37	10/20/97							
11-01-05	AX-101	45	85	40		66	08/17/97							
11-01-07	AX-101	45	85	40		66	07/26/01							BE - Cs-137
22-01-07	BY-101	40	80	40		29	07/20/96							BE - Cs-137
22-02-07	BY-102	170	260	90		31	03/30/00							Sampling equip. in well. Not logged 07-02
22-00-01	BY-103	40	80	40		13	08/12/96							BE - Cs-137
22-00-03	BY-103	40	146	106		50	11/14/02		11/19/01					No apparent change
22-03-01	BY-103	40	80	40		13	08/04/96							BE - Cs-137
22-03-06	BY-103	40	101	61		38	11/11/02		11/16/01					No apparent change
22-03-07	BY-103	40	99	59		38	11/21/02		11/26/01					No apparent change
22-03-08	BY-103	40	99	59		38	11/14/02		11/19/01					No apparent change
22-03-09	BY-103	30	98	68		38	11/21/02		11/26/01					No apparent change
22-03-10	BY-103	40	80	40		13	07/20/96							BE - Cs-137
22-05-01	BY-105	40	98	58		62	11/09/02		11/14/01					No apparent change
22-05-09	BY-105	40	98	58		62	11/09/02		11/14/01					No apparent change
22-06-01	BY-106	40	80	40		51	11/22/02		11/27/01					No apparent change
22-06-07	BY-106	35	132	97		64	11/23/02		11/28/01					No apparent change
22-07-01	BY-107	40	98	58		43	12/01/02		12/06/01					No apparent change
22-07-09	BY-107	20	99	84		55	12/14/02		12/19/01					No apparent change
22-08-01	BY-108	25	99	74		61	12/09/02		12/14/01					No apparent change
22-08-06	BY-108	40	99	59		61	12/09/02		12/14/01					No apparent change
22-08-07	BY-108	40	100	60		49	12/12/02		12/17/01					No apparent change
22-09-01	BY-109	40	80	40		30	09/01/96							BE - Cs-137
22-10-05	BY-110	40	99	59		41	12/06/02		12/11/01					No apparent change
30-00-06	C-101	30	70	40		18	02/27/02							BE - Cs-137
30-01-12	C-101	30	70	40		18	02/22/02							BE - Cs-137
30-03-01	C-103	30	125	95		54	04/12/98							Cannot log because of stairwell; 10/01 and 09/02
30-03-03	C-103	30	98	68		54	04/06/98							Water in borehole 10/01 - Cannot log
30-04-02	C-104	30	75	45		25	02/14/98							BE - Cs-137
30-04-03	C-104	20	50	30		25	02/20/00							BE - Cs-137; TD of BH is 50'

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Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
30-06-02	C-106	30	70	40		13	01/17/98							
30-06-03	C-106	30	70	40		13	01/11/98							BE - Cs-137
30-06-10	C-106	30	129	99		63	07/22/02		04/23/02					Possible change 124-126 ft Co-60
30-06-12	C-106	10	100	90		50	07/23/02		04/24/02					No apparent change
30-08-02	C-108	30	99	69	79	27	12/11/02		09/11/02	09/12/02				Definite change in Co-60 49-75 ft
30-08-03	C-108	30	70	40		2	03/15/98							BE - Cs-137
30-08-12	C-108	30	70	40		2	03/09/98							BE - Cs-137
30-09-06	C-109	30	98	68	15	42	07/22/02		04/23/02					No apparent change
30-09-07	C-109	30	100	70	10	30	12/10/02		09/11/02					No apparent change
30-00-09	C-110	30	57	27		19	03/06/02							
30-10-01	C-110	30	70	40		19	02/06/02							
40-04-08	S-104	20	50	30		49	05/19/97							Borehole obstruction
40-07-04	S-107	40	80	40		23	06/06/97							
40-07-06	S-107	40	80	40		23	05/17/01							
40-07-08	S-107	40	80	40		23	05/24/97							
40-07-10	S-107	40	80	40		23	05/02/01							
40-07-11	S-107	35	80	45		23	05/12/01							Assuming 40-04-05 is not stable
40-09-06	S-109	40	80	40	10	2	12/02/02		06/05/02					No apparent change; special request
40-12-02	S-112	40	80	40		12	12/02/02		06/05/02					No apparent change; special request
40-12-04	S-112	40	80	40		12	12/01/02		06/04/02					No apparent change; special request
40-12-06	S-112	40	80	40		12	12/01/02		06/04/02					No apparent change; special request
40-12-07	S-112	40	80	40	10	12	12/01/02		06/04/02					No apparent change; special request
40-12-09	S-112	40	80	40		12	12/02/02		06/05/02					No apparent change; special request
41-01-01	SX-101	35	80	45		14	04/13/96							BE - Cs-137
41-01-04	SX-101	40	80	40		14	04/19/96							
41-01-07	SX-101	40	80	40		14	04/13/96							BE - Cs-137
41-01-08	SX-101	40	80	40		14	04/13/96							BE - Cs-137
41-01-11	SX-101	40	80	40		14	05/05/96							BE - Cs-137
41-03-06	SX-103	40	80	40		20	04/19/00							BE - Cs-137
41-03-09	SX-103	40	80	40		20	04/18/00							BE - Cs-137
41-03-10	SX-103	40	80	40		20	04/14/00							BE - Cs-137
41-03-12	SX-103	40	80	40		20	04/12/00							BE - Cs-137
41-05-02	SX-105	40	80	40		21	04/21/00							BE - Cs-137
41-05-05	SX-105	45	132	87		21	04/29/00							BE - Cs-137
41-05-07	SX-105	45	80	35		21	04/22/00							BE - Cs-137
41-05-10	SX-105	40	95	55		21	05/04/00							BE - Cs-137
41-05-12	SX-105	35	80	45		21	05/05/00							BE - Cs-137
41-07-07	SX-107	40	75	26		54	10/16/02	04/19/02	09/26/01	04/09/02				No apparent change; HRLS 04/19/02
41-07-08	SX-107	40	76	46		54	03/16/02		09/17/01					Vent pipe obstruction FY 02
41-07-10	SX-107	40	72	32		23	05/12/00							BE - Cs-137
41-09-04	SX-109	40	102	62		58	03/08/00							Not logged due to bh contamination

Appendix H. Boreholes Projected for Monitoring During First Quarter of FY 2003

Borehole Number	Tank	Top	Bottom	Footage	Rerun Footage	Total Score	Next Log Date	HRLS	RAS Event A	RAS Event B	RAS Event C	RAS Event D	RAS Event E	Comment
41-09-07	SX-109	40	73	35		58	10/19/02	04/22/02	10/03/01	04/05/02				No apparent change; HRLS 04/22/02
41-09-09	SX-109	40	95	66		58	10/02/02		10/03/01	04/05/02				No apparent change
41-10-01	SX-110	40	80	40		54	09/28/02		09/13/01	04/01/02				No apparent change
41-10-02	SX-110	40	80	40		23	05/24/00							BE - Cs-137
41-11-08	SX-111	40	85	45		22	06/10/00							BE - Cs-137
41-11-10	SX-111	40	95	69		53	10/15/02	04/18/02	09/25/01	04/09/02				No apparent change; HRLS 04/18/02
41-12-03	SX-112	40	76	41		63	09/28/02		10/03/01					No apparent change
41-15-07	SX-115	40	90	50	10	65	09/20/02		09/25/01					No apparent change
50-03-06	T-103	30	120	90		28	03/20/99							Water in BH 01/02- not logged
50-04-10	T-104	35	88	53	10	55	11/27/02		07/31/01	01/22/02	08/29/02			Apparent change 67-68 ft
50-05-06	T-105	30	90	60		27	04/17/99							Water in BH 01/02- not logged
50-06-18	T-106	25	130	110		143	12/02/02		08/01/01	01/29/02	09/03/02			Possible increase 117-119 ft (Co-60)
50-07-07	T-107	30	70	40		42	04/07/00							No log - water filled (06/18/01)
50-08-11	T-108	30	120	90		27	05/13/99							Water in BH 01/02- not logged
51-01-09	TX-101	40	80	40		28	12/21/96							Borehole cannot be located
51-03-09	TX-103	40	98	58		55	11/09/02		05/13/02					No apparent change
51-03-11	TX-103	40	100	60	10	30	11/16/02		05/20/02					Possible change 61-62 and 90-95 ft; freq. to 6 mos.
51-04-05	TX-104	40	98	58		54	11/12/02		05/16/02					No apparent change
51-05-05	TX-105	40	80	40		64	11/13/02		05/17/02					No apparent change
51-05-07	TX-105	40	80	40	10	64	11/13/02		05/17/02					No apparent change
51-18-03	TX-118	10	80	70		25	04/19/97							
52-03-06	TY-103	40	100	60		55	11/20/02		05/02/02	05/21/02	08/22/02			Definite change 55-60 ft; report issued 5/14/02
52-04-06	TY-104	40	80	40		2	05/01/97							
52-05-07	TY-105	40	96	56		82	10/29/02		05/02/02					No apparent change
52-06-05	TY-106	40	148	108		67	08/06/02		05/08/02					Possible change 130-148 ft
60-04-08	U-104	40	110	70		94	11/25/02		07/16/01	10/22/01	01/03/02	04/10/02	08/27/02	Apparent change (74-78 and 84-89 ft) not confirmed
60-05-04	U-105	35	72	37		44	11/25/02		07/16/01	10/24/01	08/27/02			No apparent change
60-05-05	U-105	35	80	45		44	11/25/02		07/16/01	08/27/02				Possible increase 75-80 ft
60-05-07	U-105	35	75	40		7	10/14/96							
60-07-01	U-107	40	98	58		85	11/21/02		07/12/01	10/04/01	12/26/01	04/10/02	08/23/02	Apparent change 83-88 ft not confirmed
60-07-02	U-107	35	100	65		53	11/21/02		07/12/01	10/04/01	12/26/01	04/15/02	08/23/02	Apparent decrease 90-100 ft not confirmed
60-07-10	U-107	40	99	59	10	85	11/24/02		07/09/01	10/24/01	12/27/01	04/15/02	08/26/02	Apparent change (SGLS); 53-65 ft not confirmed
60-07-11	U-107	40	100	60		85	11/24/02		07/12/01	10/24/01	12/27/01	04/15/02	08/26/02	Apparent change (SGLS); 73-95 ft not confirmed
60-08-04	U-108	35	100	65		56	11/25/02		07/09/01	10/25/01	12/28/01	04/15/02	08/27/02	No apparent change
60-10-01	U-110	35	75	40		11	11/24/02		07/17/01	10/04/01	12/27/01	04/11/02	08/26/02	No apparent change
60-10-02	U-110	35	75	40		11	11/02/00							
60-10-05	U-110	35	75	40		11	11/03/00							
60-10-11	U-110	35	75	40		11	11/24/02		07/17/01	10/04/01	01/02/02	04/11/02	08/26/02	No apparent change
60-11-07	U-111	35	75	40		37	10/20/02		10/25/01					No apparent change
60-11-12	U-111	35	75	40		37	10/31/02		11/05/01					No apparent change
60-12-03	U-112	35	75	40		12	04/21/00							